THE CRYSTAL-SET RADIO

100 more Crystal Set plans

Everyone wants to make a RADIO.

The simplest radio is a **CRYSTAL SET**. (Sometimes called a **Crystal-Set Radio** or **Xtal Radio Set** or **Crystal Diode Radio**.)

However a **Crystal Set** needs a number of components that are very hard to get: (tuning capacitor with knob) and (crystal earpiece for $1.25).
The "air" TUNING CAPACITOR (20p to 415p) is not easily available and the postage is expensive. The germanium diode is a special component and the aerial coil wound on a ferrite slab is difficult to obtain.

But you don't need these components. They can be substituted.

There are hundreds of websites on the internet describing the **CRYSTAL SET** and if you want to build a "normal" set, you can Google these sites or **100 more Crystal Set plans**. Many of them sell kits too.

But this article is different.

We are going to have all the fun of making a **CRYSTAL SET** but with modern components and easy-to-make components and with an amplifier stage. The output is loud so you don't need a long antenna. And we are going to make our own TUNING CAPACITOR and a very simple aerial coil (called a FRAME AERIAL) as well as replacements for the germanium diode (use a TRF radio IC or a transistor) and in place of hi-impedance headphones (use a piezo diaphragm) and a crystal earpiece equivalent (a piezo diaphragm).
It's even better to have one of each type of component so you can compare the performance, so no matter how many parts your get, nothing will be wasted.

We are also going to explain the fundaments of how the circuit works as even the simplest circuit has a number of very important features that are used in many other circuits.

But first we are going to learn about the components and how they combine to make the circuit work.
When two or more components are connected together they sometimes produce a completely different result to the capabilities of either item.
This is the case with a capacitor and inductor in parallel. An inductor is simply a coil - turns of wire on a cardboard tube - called a former and the centre of the coil is AIR. It is called an air-cored coil or air-cored inductor.
Each component (the coil and capacitor) is called a PASSIVE DEVICE - in other words it does not amplify, but when the are connected together they create a result very near to amplification. And they also produce a result of picking up a huge number of signals and only allowing one signal to appear across the pair. A truly amazing result.

We start by placing a capacitor across the coil.
There is so much activity in the air, from radio, TV, taxi and mobile phone usage that the air is filled with electromagnetic radiation.
This radiation will cut the turns of the inductor (the coil) and produce a microscopic voltage in the turns. This is enough to start the two components passing energy back and forth at a rate

determined by their values. This is the basis of our first discussion.
These two components are called a TUNED CIRCUIT and make up our first building block called THE FRONT END.
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THE FRONT END

This consists of a coil and capacitor. These two components are in PARALLEL and the signal (called the RADIO SIGNAL or RADIO WAVE) passes through the centre of the coil and produces a voltage in the turns of the coil. The electromagnetic wave has to pass through the centre of the coil.
This voltage is the result of a mass of signals that are interfering with each other and producing a signal called BACKGROUND NOISE.
The voltage can be increased by an external aerial (called an ANTENNA) and it consists of ALL THE LOCAL radio stations (and everything else).
The voltage is a mass of signals and is absolutely useless as it represents all the stations AT THE SAME TIME.
However, across the coil is a capacitor and these signals charge the capacitor with the very small voltage produced by the energy of the signals. When the capacitor is charged, it delivers its voltage to the coil. The coil accepts the energy and converts it to magnetic flux.
After a very short period of time the capacitor becomes discharged and the magnetic flux collapses and produces a voltage in the coil of the opposite polarity to charge the capacitor again in the opposite direction.
These two components keep oscillating back and forth, using the tiny amount of energy from the stations.
There is a natural frequency for the capacitor and coil to pass energy back and forth and one of the stations will provide energy to assist this natural frequency.
When this happens, the amplitude of the signal increases and the signals from all the other stations cancel themselves out and only one signal (waveform) remains.
This signal is called the NATURAL FREQUENCY OF RESONANCE and it corresponds exactly to one of the radio stations.

The end result is a waveform that is the exact same frequency as one of the radio stations and when voice or music is played, the amplitude of the waveform increases and decreases. This will be the signal you hear in the earpiece or speaker.
It is called an AMPLITUDE MODULATED signal and that is where we get **AM RADIO** from.

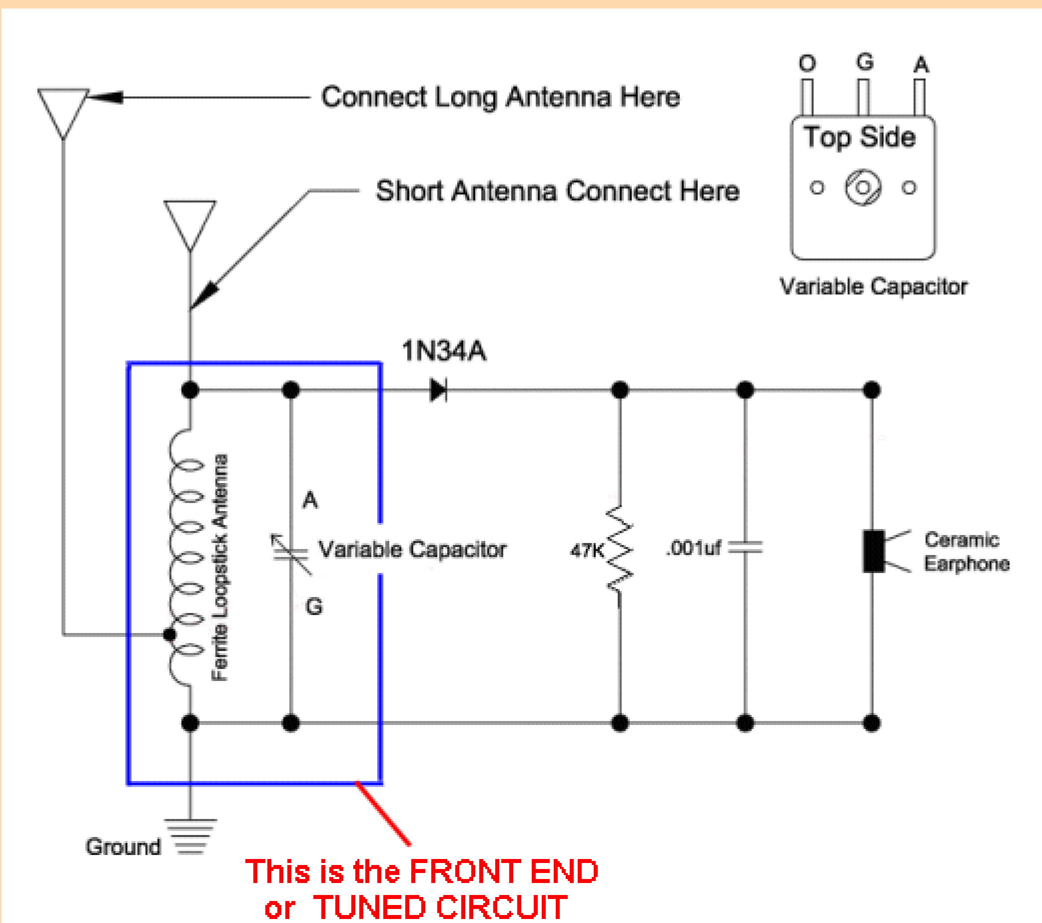
Understanding the concept of a CAPACITOR and INDUCTOR in parallel is very important. They form a TUNED CIRCUIT that has a natural RESONANT FREQUENCY.
Here is a very similar analogy. You have a heavy metal ball on a long string attached to the gutter on your house - just like a pendulum. You can push the ball very lightly with a finger and after a number of pushes you will be able to get the heavy ball swinging in a very large arc.
The only way to keep it swinging is to push it very lightly at exactly the right time. If you push it at the wrong time it will eventually stop swinging.
The parallel tuned circuit is exactly like the ball. It wants to oscillate at a particular frequency.
All the radio stations are pushing and pulling the circuit at the wrong times and nothing is happening. But one radio station pushes at exactly the right time and the circuit starts to oscillate.
All the other stations are fighting each other just like one person pushing the ball sideways and another pushing the ball from the opposite side. The results cancel each other and you are the only one assisting the swing.
The TUNED CIRCUIT can also be called a FILTER with a very narrow BAND-PASS frequency but our simple explanation describes the operation much more clearly.

There are a few other terms used to describe the components in the font end:

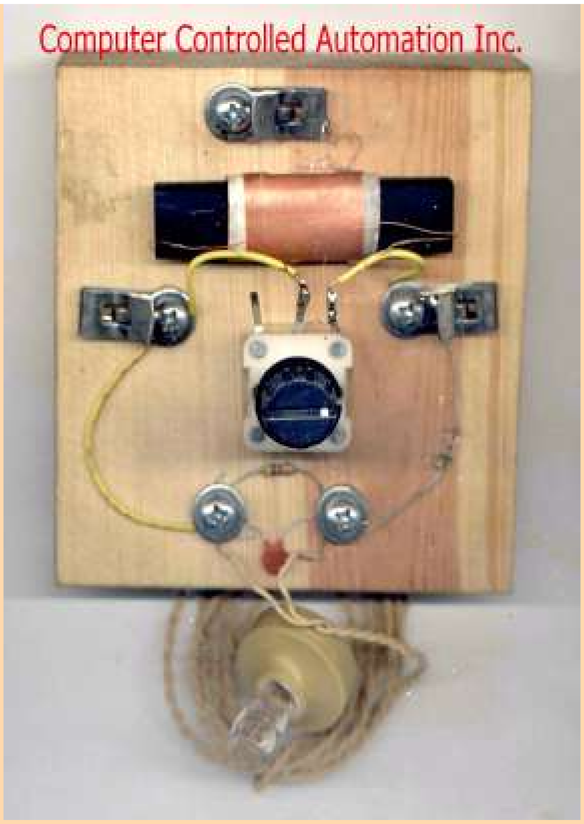
LOOP STICK ANTENNA -This is an alternate name given to the coil of wire wound on a ferrite rod or slab. It also has the name ROD ANTENNA or FERRITE ROD ANTENNA.
The winding can be enamelled wire or flexible wire called LITZ WIRE. This is very fine strands of enamelled wire twisted together and covered in cotton. The purpose of changing a thick wire to lots of very thin wires is to prevent the radio signals creating loops of signals within the wire and these signals will cancel each other and not produce a signal out the end of the wire.
In our experiments, we have not noticed any difference in a coil made with ordinary enamelled wire and Litz wire.

Here is a set of components to make your own Crystal set from **Scott's Electronic Parts**:
You can see the rod antenna, germanium diode, crystal earpiece, capacitor and resistor. The kit costs about $9.00 plus postage and includes knob, clips and screws but no board to mount the parts.

Here is the circuit for a Crystal Set:

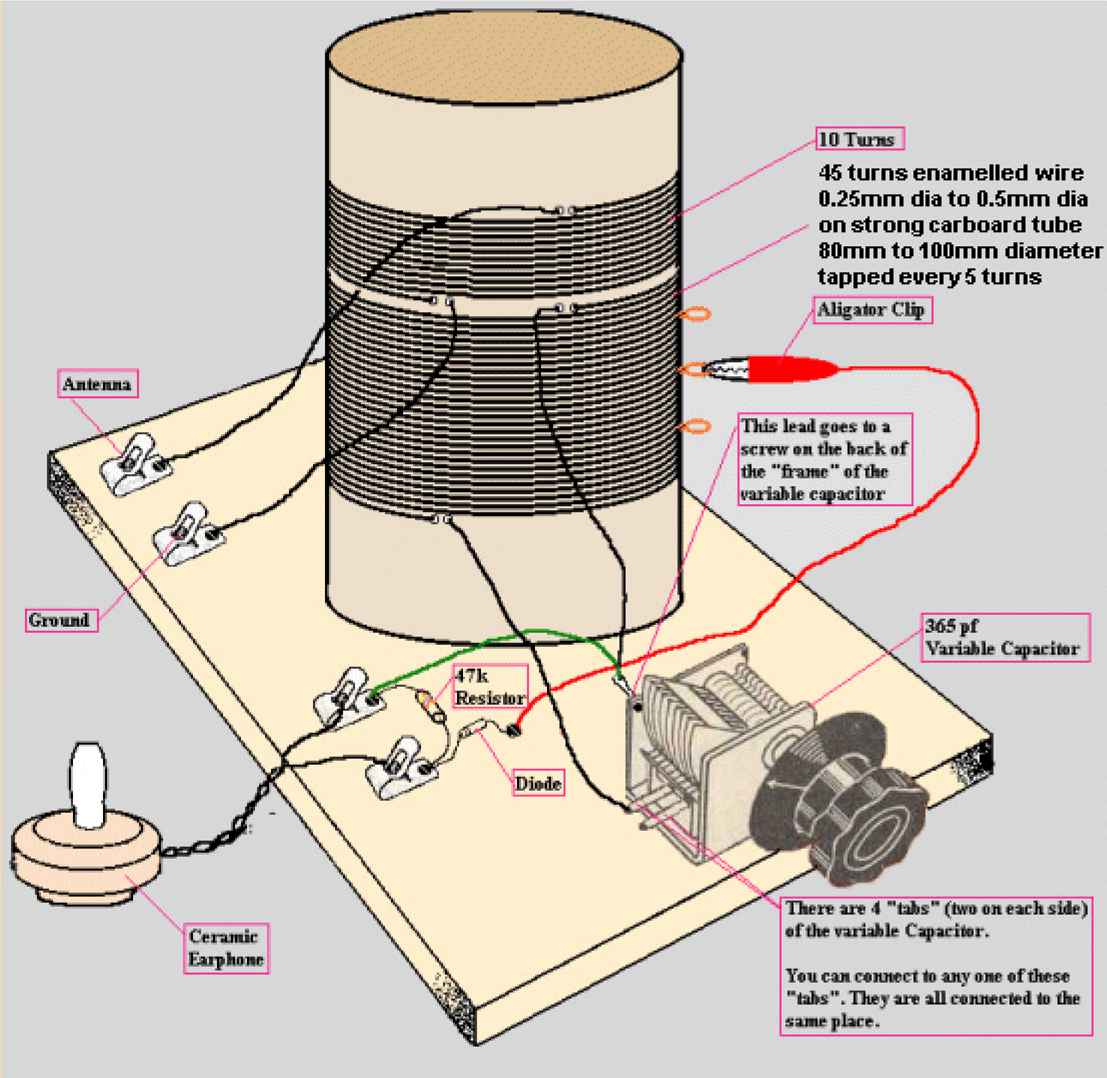


Here are the components mounted on a board called BREADBOARD:



The top clip connects to a long antenna. The left clip connects to ground and the right clip connects to a short antenna.

Let me clear up a point. You do not need a ferrite rod antenna for the coil. You can use an ordinary coil wound on a cardboard tube and it will work just as well if you are using an outside antenna.
Here is the circuit using a home-made coil.



The tappings on the coil allow a wide band of radio stations to be tuned.
Each tapping allows a different portion of the band to be covered.

The next part to understand is this:
The coil and capacitor must not be LOADED. In other words, you cannot connect anything to this combination because the signal it is producing will be "taken away" or "removed" or "considerably reduced" by the item you are connecting to the circuit.
These two components are called a TUNED CIRCUIT and when they are not loaded they pick up all the radio stations, one station at a time, when the natural resonant frequency of the coil and capacitor exactly match the frequency of the radio station. The circuit actually "rejects" all the radio stations except one. Because all the other stations are trying to make the Tuned Circuit oscillate at a different frequency and it does not do this.
The result of the TUNED CIRCUIT oscillating under NO LOAD conditions produces a waveform that is very high and this gives the circuit GOOD SELECTIVITY. The circuit can select one station and reject nearby stations.
It also has good SENSITIVITY as it can pick up weak stations.
If you load the circuit, only the strongest signal will be detected and it will be spread across the full range of the tuning capacitor.
Obviously the theory is more-complex but we are explaining the end-result.
Theory talks about the "Q" value of the coil and this is its ability to produce a very good output when the magnetic flux collapses and the "Q" value increases when the circuit is not loaded. .
Although these voltages are very small (in the order of microvolts or millivolts) the result is very important as the rest of the circuit will be amplifying this waveform a few thousand times.
As we explained above, pushing the weight on a string only needs a push of 1 cm and eventually the weight will swing 1 metre. This is a gain of 100:1 The same thing happens with the tuned circuit. The incoming radio signal is in the order of microvolts, but the coil and capacitor will produce a signal as high as 500 millivolts. This is an improvement or "gain" of more than 1,000 and is referred to as the "Q" of the circuit.
You will also notice the TUNED CIRCUIT is not connected to any supply voltage. It does not have

be connected. It generates its own waveform from the signals in the air.
It should not have any DC current flowing through it via the supply as this would put a load on the circuit and reduce its operation.

However we must "pick-off" the signal so it can be amplified.
This must be done with a very high impedance circuit.

THE CONVERTER (detector) - THE DIODE

The next part of the circuit is the CONVERTER. Commonly called the DETECTOR.
It converts the RADIO FREQUENCY signal to an AUDIO FREQUENCY signal.
This is the job of the DIODE.
The radio frequency signal is a very high frequency signal (say one million cycles per second) and it is sending a tone of one thousand cycles per second through the air-waves.
What is happening is this: The one megahertz signal has a certain amplitude and over a range of the first one-thousand cycles, the amplitude gradually decreases and then increases again. If you look at the tops of this 1,000 cycles you will see a waveform that corresponds to the one kilo-Hertz signal.
The 1MHz signal is picked up by the coil and capacitor in the front end and makes it oscillate.
The radio frequency signal is gradually getting larger over 500 cycles then smaller over the next 500 cycles and this increase and decrease represents the 1,000 cycles per second tone.
This is the waveform (the signal) that passes through the diode. This will be explained further in a moment.
The diode does not pass any signals less than 200mV as the first 200mV is lost in the junction of the diode. This means the signals start to appear on the other end of the diode when they are above 200mV.

This is how the diode works:
Across the crystal earpiece is a capacitor. The capacitor gets charged via the diode.
The diode is present to stop the capacitor getting discharged when the waveform is in the wrong direction. (by this we mean - when the waveform is lower or smaller in amplitude than the voltage on the capacitor).
And the waveform is in the wrong direction about 50% of the time. To charge the capacitor for one-half-cycle requires 500 "little increments" in voltage with each increment adding a microscopic increase in voltage. We don't want this voltage to reduce when the waveform is reversing direction and the diode stops the voltage flowing back to the Tuned Circuit.
During the next half of the cycle when the pulses are getting smaller and smaller, the voltage on the capacitor is "bled off" by the load resistor.
The crystal earpiece detects this voltage. What we mean, is the diode allows the voltage to rise (increase) on the capacitor via lots of little "pulses" and the voltage increases in the form of a sinewave to a maximum amount. This voltage is passed to the crystal earpiece.
Once the voltage rises to a maximum, the little pulses of energy are not quite as strong, and the voltage on the capacitor reduces to form the second portion of the sinewave. This voltage is always being passed to the crystal earpiece and you can hear it as an audio signal.

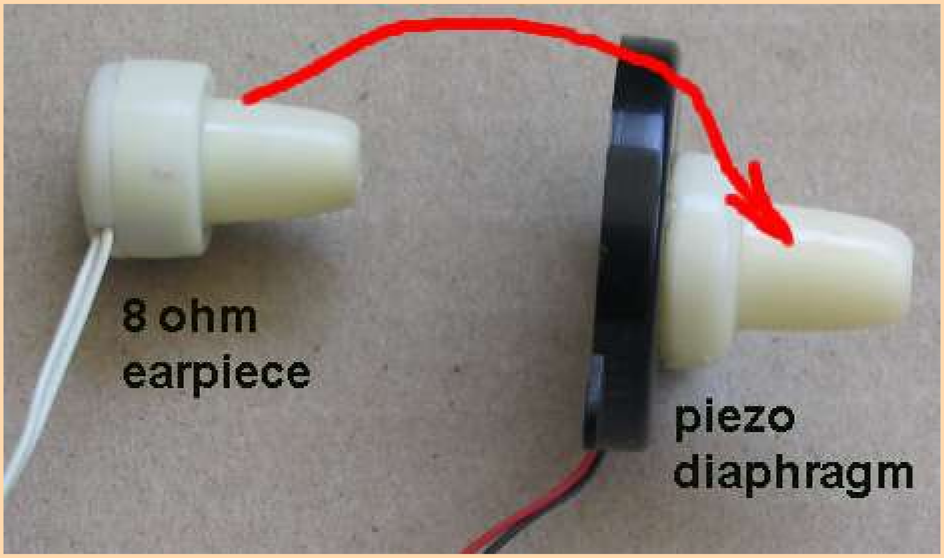
GERMANIUM OR SILICON DIODE

The preferred type of diode for a Crystal Set is germanium. This is because it drops only about 0.3v.
But a silicon diode can be used, even though it drops about 0.7v, if the radio stations are very loud (close by).
You have to remember, you need a very good aerial (and a water-pipe earth) to get any results with a Crystal Set because you are asking the signal to provide the energy to drive the earpiece.
By simply adding a transistor, you are improving the performance 100 times and the long antenna can be reduced to a FRAME ANTENNA and the earth can be the metal frame of your soldering iron.

THE EARPIECE or EARPHONE
also The Magnetic Earpiece or CRYSTAL EARPIECE

The earphone or earpiece used in a Crystal Set must be a high impedance device because the crystal set does not produce a high current and cannot drive a low-impedance earpiece. That's why a CRYSTAL EARPIECE is ideal.
It has a crystal glued to the back of the earpiece and connected to its top surface is an aluminium diaphragm. When the crystal expands and contracts as a result of a voltage applied via two electrodes, the diaphragm moves and you can hear the signal. It exhibits a very high impedance

because it consists of a crystal and no coil of wire is contained inside the case.
If you do not have a Crystal Earpiece, you can make your own from the shell of an 8 ohm earpiece and a piezo diaphragm. Only the front part of the earpiece is used.



Make your own Crystal Earpiece

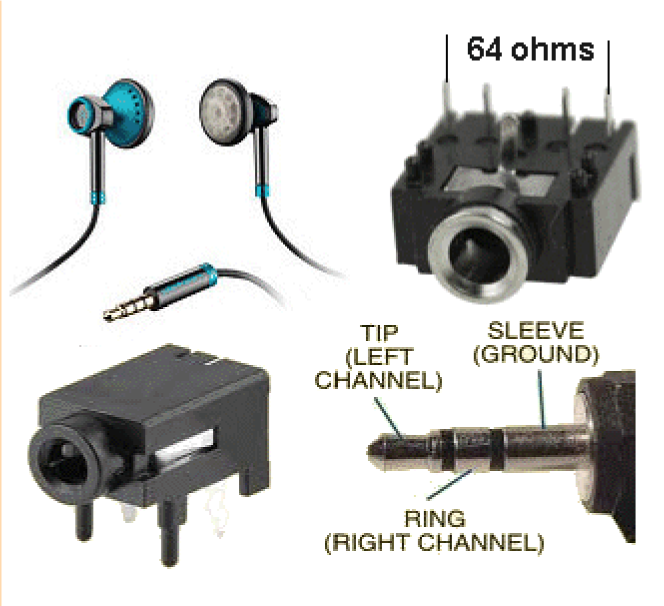
Hit the 8 ohm earpiece on the side and the front comes off. Glue the front onto a piezo diaphragm with hot-melt glue. See photo above.
The piezo diaphragm is a ceramic substrate that deflects in the presence of a voltage. It is quite sensitive and you can hear the audio quite clearly.
The waveform emerging from the diode in a Crystal Set is called AUDIO and although it has an amplitude of a few hundred millivolts, it does not have any current associated with it. The crystal earpiece and the piezo diaphragm react to this voltage.

THE 8ohm EARPIECE

The 8 ohm earpiece can be used with our 8ohm Buffer stage shown below.

16ohm 32 ohm and 64 ohm EARPIECE(s)

Earpieces and headsets from mobile phones are 16 ohm or 32 ohm per earpiece and are terminated via a stereo 2.5mm or 3.5mm plug. The earpieces are connected in SERIES to get the best coupling to our radio circuits and you need to find the two pins on a stereo socket to produce series connection. Get a multimeter and switch to "ohms." Try all the pins and you will get a click in the left ear then the right ear. Keep searching until you get a click in both earpieces at the same time. Use these two pins.



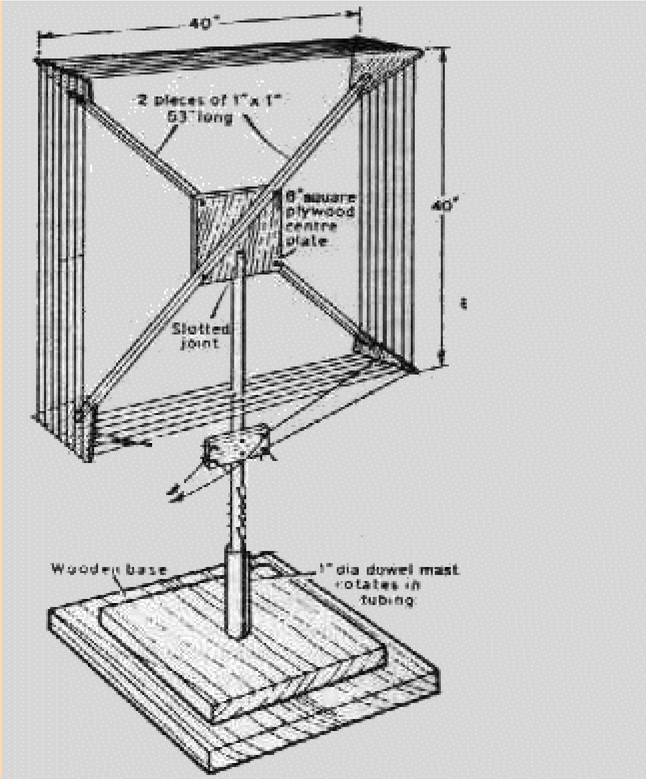
Stereo mobile phone headset - unusually 32R or 64R

PROBLEMS

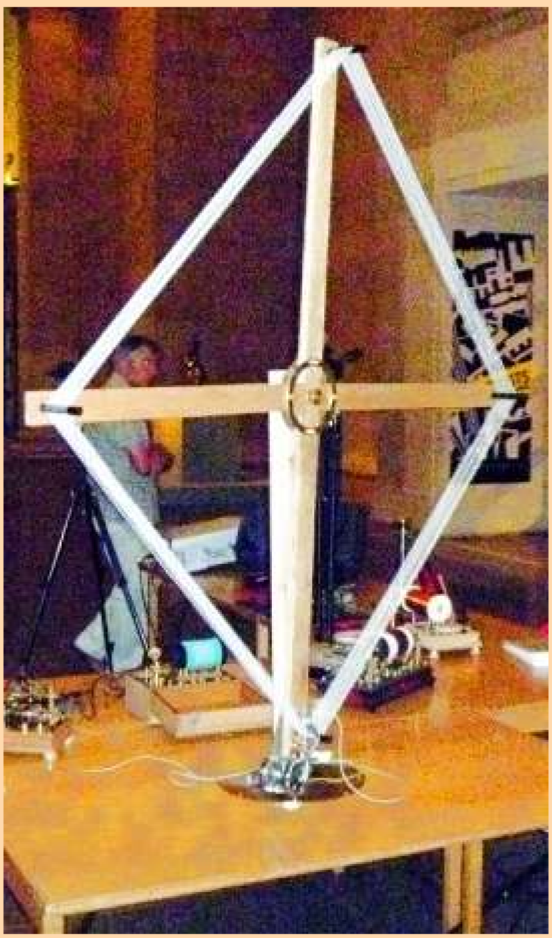
The biggest problem with a Crystal Set is the need for a long antenna.
The first 200mV to 300mV of a signal is lost in the diode and you need a long antenna to pick up a signal so the output of the TUNED CIRCUIT has enough voltage to drive the high-impedance earpiece.
This requires an outside aerial 5 metres long and 3 metres high.
This is not practical for most hobbyists so we will be adding an amplifying stage to the crystal set so a shorter (smaller) aerial can be used.

THE FRAME AERIAL or FRAME ANTENNA or FRAME COIL

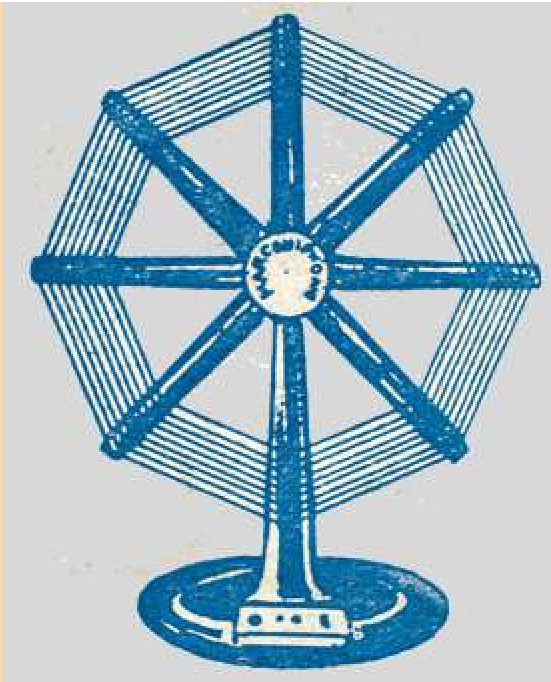
The aerial coil shown in the photo above is a ferrite slab with about 80 turns of Litz wire. You can find one of these in an old broken AM radio or from a parts-shop. In the instructions below we show how to make your own Ferrite Rod Antenna
An equally-good substitute is a frame antenna made by winding insulated wire in a rectangle around wooden sticks.



FRAME ANTENNA



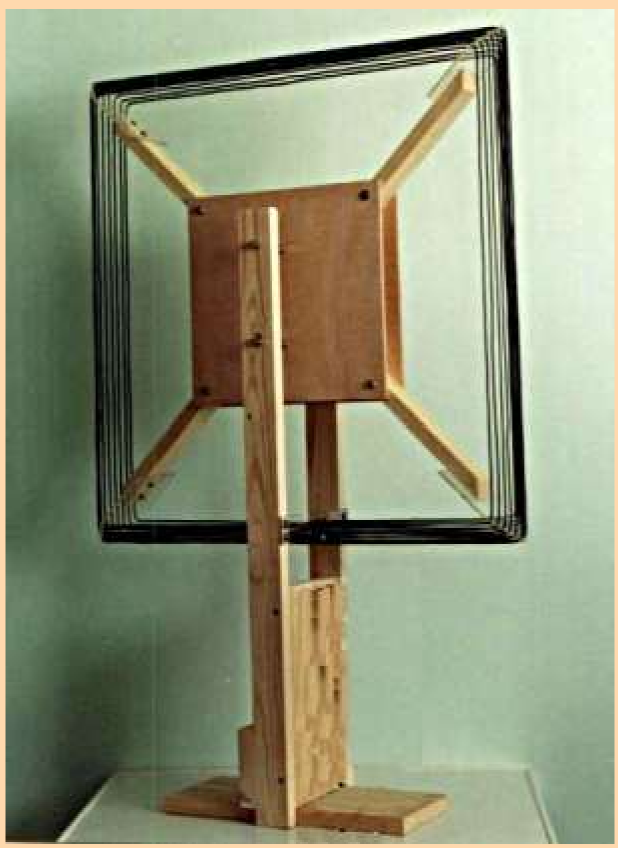
15 turns on a diamond frame



One of the earliest Frame Antennas

The Frame Aerial can be as large as 100cm x 100cm or as small as 10cm x 10cm around a plastic chocolate box.

Here are two FRAME ANTENNAS:



This will work just as good as a ferrite slab antenna. The slab antenna is just 100 times smaller. The slab antenna was invented so a transistor radio could be built in a small case. But if it is not available, you can wind 20 turns around a plastic chocolate box and it will work just as good.

Alternately you can wind 20 turns around a biscuit tin. Put a pencil on the tin and wind the turns over the pencil too. Remove the pencil and it will be easy to remove the turns. Use tape to keep

the turns together.

The FRAME AERIAL does two things. It picks up the radio waves and it becomes the coil (called the INDUCTOR) in the TUNED CIRCUIT. It must be placed away from metal objects, such as a refrigerator.

BASKET WEAVE COIL

There is no point making a complex BASKET WEAVE COIL as it will not work any better than simply jumble winding all the turns at the maximum circumference of the coil, because the energy capturing capability of the coil relies entirely on the amount of flux lines passing through the centre of the coil.
By increasing the centre of the coil, the amount of flux is increased for the same coil size.
In fact, the simplest and cheapest is to wind turns around a box, as explained later in this article, or make a frame antenna as shown above. Technically speaking, a round coil has the best performance but only by a few percent.

A BASKET WEAVE COIL

THE VARIABLE INDUCTANCE TUNING COIL

Whenever the size or shape of the coil is changed, (or the number of turns), the natural frequency of the Tuned Circuit will change and a different radio station will be picked up.
This means tuning across the band can be done by altering the characteristics of the coil while keeping the value of the capacitor fixed.
Changing the inductance can be done in many different ways.
The coil can have taps every 5 turns and an alligator clips selects the correct tap. But very few radio stations will correspond exactly to each tap.
Another way is to have a slider move up and down the turns as shown in the following image:

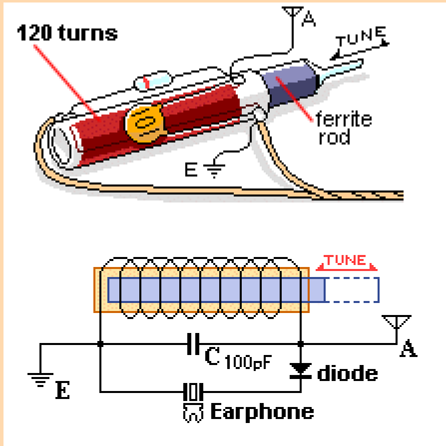
The slider makes contact where the insulation has been removed. But it may touch two turns at the same time and create a "shorted turn" and reduce the "Q" of the coil.

Another way is to move a ferrite bar (rod) in and out of the coil:

THE SLUG TUNED COIL

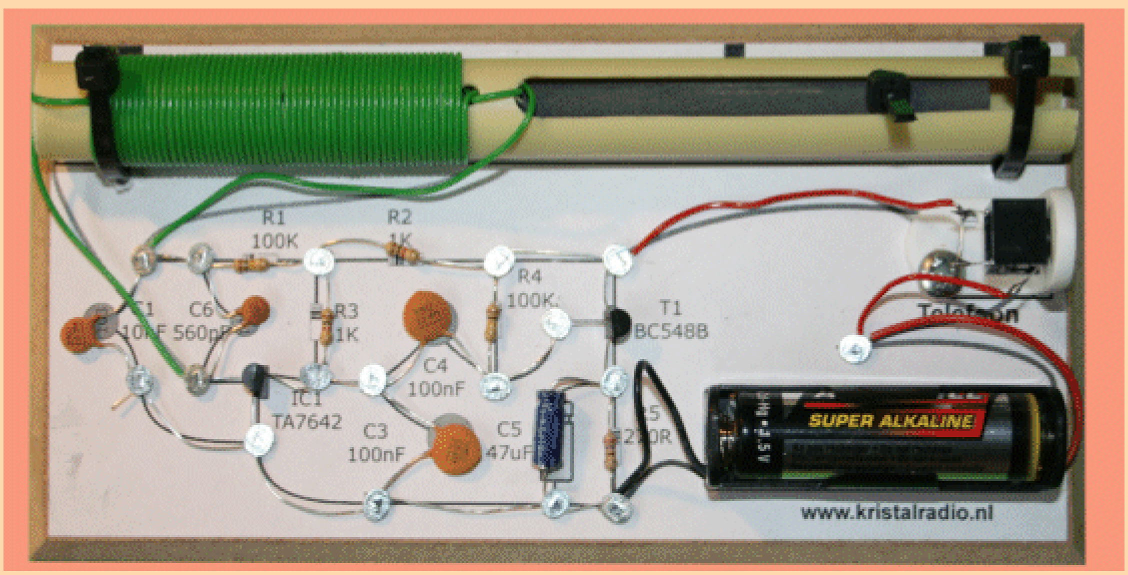
To tune across the radio band, the natural frequency of oscillation of the TUNED CIRCUIT must be adjusted (changed). This can be done by changing the value of the capacitor or the value of the inductor.

The value of the inductor can be changed by adding or removing turns or changing the amount of magnetic material in the centre of the coil.
A ferrite bar can be screwed in and out of the coil or slid in and out and this component is called a **SLUG TUNED COIL**.
The following diagram shows a **SLUG TUNED CRYSTAL SET**:



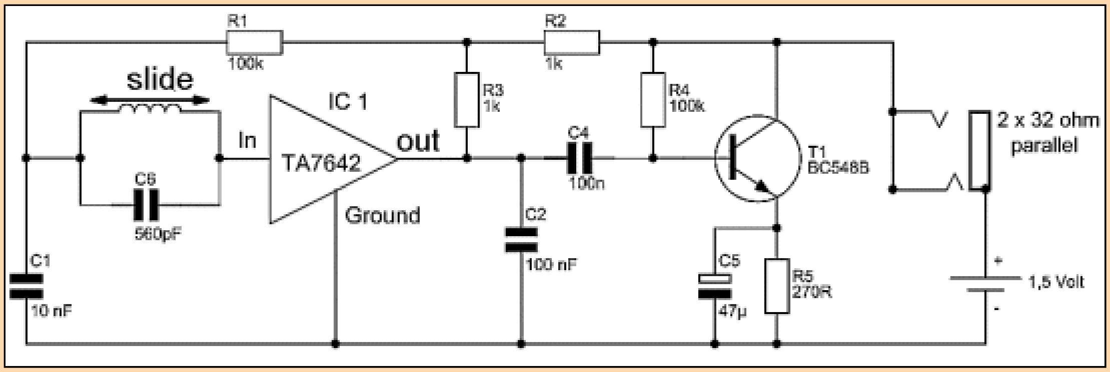
By changing the value of the 100p capacitor, different parts of the band can be picked up.

The photo shows a slug tuned coil using 60 turns of insulated wire on a 10mm tube (or any tube that will fit over a 8-10mm ferrite rod) and a circuit containing an AM radio chip plus a buffer driver transistor:



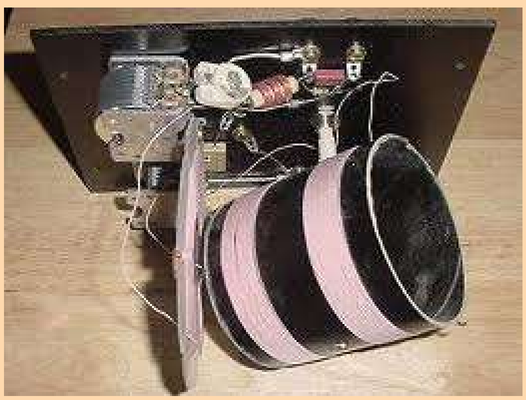
A SLUG-TUNED RADIO

The circuit above is has a broad-band amplifier consisting of 10 transistors (IC1) and they are directly coupled (connected) to each other because it is not possible to "manufacture" a capacitor inside the IC. The IC has 3 terminals (pins, legs) and it looks like an ordinary transistor. Experimenting with this type of IC has shown that it is no better than 2 ordinary transistors connected in a direct-coupling arrangement.



Here is the address of the site for the slug-tuned radio.
http://www.kristalradio.nl/
Unfortunately the site is in Dutch and the kit is not available. However the photos give a clear picture of the how the parts are connected.

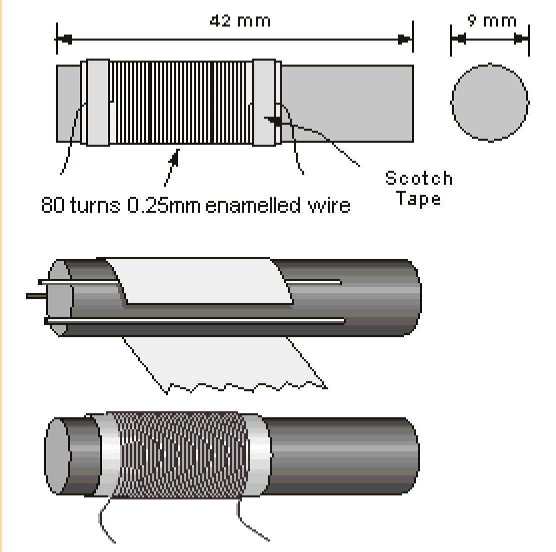
The inductance of the coil can also be altered by winding another coil and placing it near the first coil so that the magnetic field interacts with each other and changes the inductance of the circuit. This is called a VARIABLE INDUCTANCE TUNING COIL.
You can have one coil inside the other, two coils near each other or two flat coils side-by-side. Any two coils will interact with each other.



An Inductive TUNING COIL called a VARIOMETER

MAKING YOUR OWN FERRITE ROD ANTENNA

You can make your own FERRITE ROD ANTENNA by winding 60 to 80 turns of 0.25mm enamelled wire onto a 9mm ferrite rod or slab. If you wind it on a paper sleeve, you can move the coil along the rod to get the best performance. When the rod is slid out of the coil, the inductance changes considerably. However the inductance does change very slightly when the coil is moved along the rod.



Make your own ferrite antenna

Now we come to the tuning capacitor::

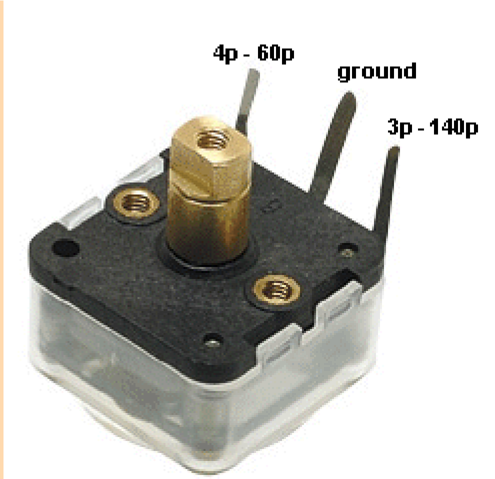
THE TUNING CAPACITOR

The "C" in the "LC" TUNED CIRCUIT can be fixed or variable. When it is variable, it is called a TUNING CAPACITOR. The sheets of aluminium in the air tuning capacitor below are called PLATES and the moving plates are called VANES. The fixed plates make up the STATOR.
The space between the plates is AIR. The photo shows a single capacitor. If two capacitors are connected to the same shaft it is called a GANGED CAPACITOR.
The plates do not come fully out of mesh and that's why the capacitor has a minimum value. The maximum capacitance is when the plates are fully meshed. The odd shape of the plates is designed to produce a fairly constant increase in capacitance as the plates are engaged.

An air tuning capacitor:

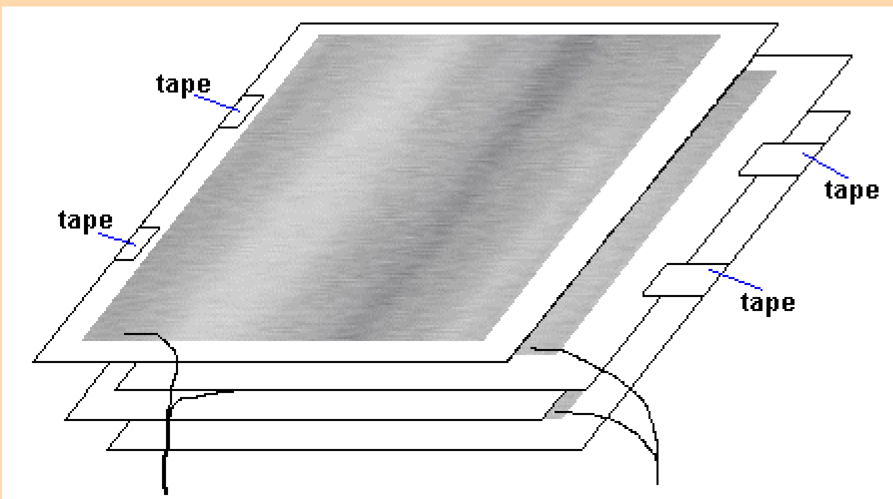
Air Tuning Capacitor
(Variable Capacitor)

The capacitor can be made much smaller by using thinner vanes and placing plastic between the vanes. Plastic increases the capacitance about 3 times to 10 times.



Tuning Capacitor as found in a pocket radio

The tuning capacitor can be replaced with a home-made equivalent that will work just the same.
You need:
4 sheets of aluminium foil (cooking foil) 10cm x 10cm.
4 sheets of thin cardboard 15cm x 20cm (cut A4 sheets in half).



HOME-MADE CAPACITOR

Tape a sheet of aluminium foil to each sheet of cardboard with sticky-tape around all 4 sides. Take one strand of wire from a length of hook-up flex and sticky-tape the end to each sheet of aluminium to make good contact. Place 2 sheets on top of each other and move the top sheet slightly to the left and sticky-tape the edge so they don't move. Do this with the other two sheets but move the top sheet to the right. Now interleave the sets. Connect the wire from the first sheet to the third sheet. Connect the wire from the second sheet to the fourth sheet.
The cardboard (or paper) between the aluminium sheets increases the capacitance three times.
The capacitance decreases when the sheets are moved apart and the capacitance increases when the sheets are moved in. The capacitance also INCREASES when the sheets are squashed together such as when a book is placed on them.
You can also make a smaller capacitor by making each sheet smaller and using 6 sheets. You can then add a 100p or 220p in parallel with the home-made capacitor, to select the lower part of the band.

EACH CIRCUIT

Each circuit we describe in the following set of circuits is an improvement or advancement on the previous. We also offer a number of different types of aerial coils, amplifying stages and earphones. Some of the circuits use easy-to-obtain components and home-made equivalents for hard-to-get items. There will be something in this section for everyone to build.

In all radio circuits you will encounter **TWO MAIN PROBLEMS**:

If the FRONT END (the Coil and Capacitor) is loaded too much by the "pick-off" of the amplifying stages, you will only get one station.
If you get squealing or "motor-boating," try a different circuit and layout as the components you are using, plus the voltage of the battery, will need changing.
You cannot always increase the voltage of the supply and get a louder output. Sometimes the increased voltage will stop the circuit working or it may introduce too much gain that the circuit starts to squeal.
The Radio IC (ZN414) DOES NOT WORK on a voltage above 1.5v and some of the transistor circuits completely stop working with a higher voltage. This has to do with the biasing arrangements and if the circuit is designed for a low voltage, you need to keep to the suggested voltage and experiment with a slight increase in voltage and see what happens.
Building a radio is not easy as the enormous amount of amplification of the combined stages creates a feedback loop via the power rail that sets the circuit into oscillation. This effect gets worse with a higher supply voltage and we will explain this further with each of the circuits.

MAKING A CRYSTAL SET

You can buy a **CRYSTAL SET** kit (see the photo of the kit, above) or the individual components (a kit is the cheapest) or use the replacement for the **FERRITE ANTENNA COIL** (16 turns to 20 turns on a 150mm biscuit tin) and/or the **TUNING CAPACITOR** made from aluminium foil and cardboard sheets.
You will need an outside antenna and an earth (such as a water tap or the frame of your soldering iron) to pick up the radio stations.
If you cannot put up an outside antenna, you will need to add one or more amplifying stages and this will allow you to reduce the length of the antenna and increase the volume of the audio.

ADDING AMPLIFYING STAGES TO A CRYSTAL SET

You can add two different types of amplifying stages to a crystal set.
You can connect amplifying stage(s) to the FRONT END and these will be designed to put less load on the front end so the sensitivity and selectivity increases. These stages work at the frequency of the radio signal and they are called RF STAGES (Radio Frequency Stages).
You can build these stages out of individual components or use a chip called a RADIO CHIP or RADIO IC (integrated circuit) for less than $2.00.
The chip contains 5 stages of amplification and these are RF stages (or RF AMPLIFYING STAGES) and the concept is called TRF. (Tuned Radio Frequency).
It is not easy to get this type of amplifier working because the stages produce a very high overall gain and you get a lot of "motor-boating" and squealing if the gain is not controlled. The gain must be reduced when a strong signal is being passed through the circuit because a strong signal will produce a large output and this will be so large that some of the waveform will find its way to the front of the amplifier via the power rail and start to be amplified again. To prevent the output getting too large, the circuit has a negative feedback line - called the AGC line - Automatic Gain Control.
It would be very difficult to reproduce these 5 stages of amplification with discreet components and that's why it is best to use an IC.

The next stage is a DIODE to convert the RF (Radio Frequency) to AF (Audio Frequency). This can be done with the diode-characteristics of a base-emitter junction in a transistor and we will show the alternatives.

Any stages after the diode are AUDIO STAGES or AUDIO AMPLIFIER STAGES.
The main job of the AUDIO AMPLIFIER is to increase the DRIVE CAPABILITY.
In other words, increase the current capability of the circuit for an 8 ohm speaker or 8ohm earpiece (or 16 or 32 ohm).
This is a very difficult thing to do and requires at least 2 stages.
The LOAD you can put on a Crystal Set must be 10,000 ohms or higher. (if you put a lower resistance (impedance) on the output, you will load the FRONT END and reduce its ability to separate the stations.
That's why a crystal earpiece is normally used with a crystal set. It puts almost NO LOAD on the circuit.
If you put a load on the circuit the result will be only one or two stations across the whole dial and only the most powerful station will be received.

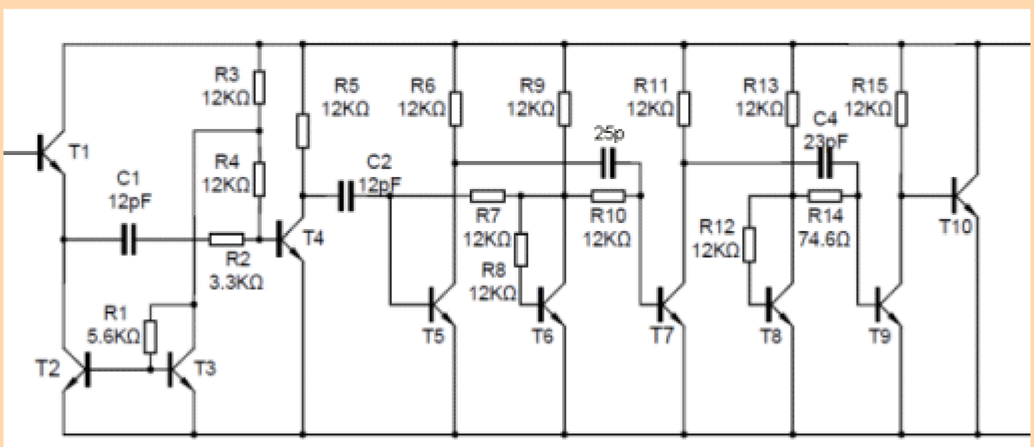
If you don't have a crystal earpiece, you will have to use an 8 ohm earpiece. This will require an IMPEDANCE CONVERTING CIRCUIT of 1,250:1
This is a simple way of saying we want the 8 ohm earpiece to appear as 10,000 ohms to the

crystal set.
To produce an overall gain of 1250, we need two stages of amplification.
If a transistor has a gain of 70, it will it will produce an impedance conversion of 70 times. This is a realistic value. Transistors with a gain of 200 will have a gain of about 70 when fitted to a circuit.
This means the other transistor needs to have a gain of about 20 and that is easy to achieve.

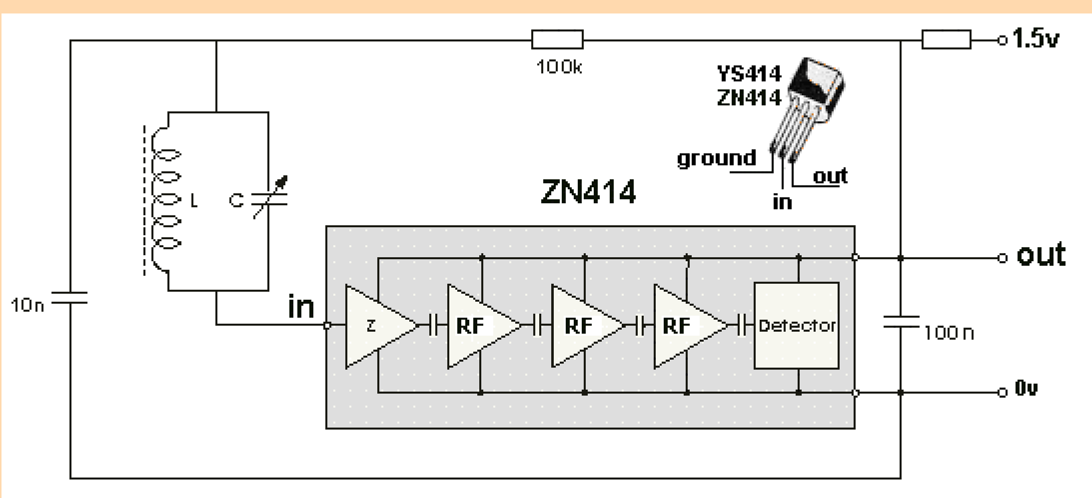
ADDING AMPLIFYING STAGES TO THE FRONT OF A CRYSTAL SET

Adding stages to the front of a crystal set are called RF STAGES (Radio Frequency Stages) because they amplify the RADIO STATION SIGNAL.
It does not matter if you amplify RF signals or AF signals. The result is the same.
The only difference is this: The frequency of RF signals is much higher (1,000 times higher) and the coupling capacitors can be much smaller.
This allows an RF amplifier to be built into an IC - called a Radio Chip.
One of the most popular Radio IC's is ZN414 or YS414. This chip has been copied by other manufacturers as: MK484, TA7642 and LMF501T.
All the chips are the same but the pinout is different.
These chips work on a 1.5v supply and if the voltage is increased above 1.5v, the gain of the stages increases to a point of total distortion.
To prevent strong signals producing distortion on 1.5v supply, the output is passed back to the input via a 150k resistor. This feedback line is called the AGC (Automatic Gain Control).
The chip contains 5 stages of amplification plus a stage that converts the RF signal to AF (Detector Stage). This means the signal diode in a Crystal Set is not needed.

Here is the circuit of the TA7642 Radio Chip. It performs the same as the ZN414 Radio Chip.



Here is the BLOCK DIAGRAM of the ZN414 Radio Chip:

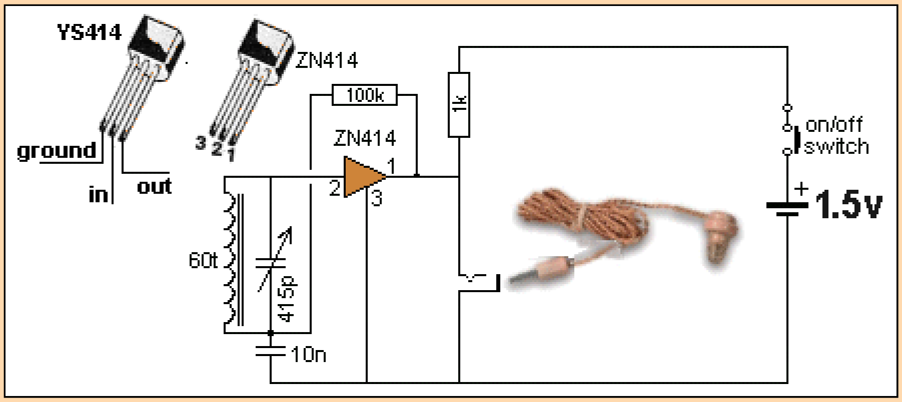


The ZN414 chip can be purchased from Talking Electronics for $1.00 plus postage

USING THE ZN414 RADIO IC

By using the ZN414 radio IC (or any if the equivalents) you can create a POCKET RADIO to drive a headphone or speaker.
But it is not easy to use the chip. The main problem is receiving the strong signals without producing distortion and then being able to pick up the weak stations.
A fixed 100k feedback resistor does not provide adequate control and a TRF radio has limited capabilities.
That's why radio manufacturers make SUPERHETRODYNE receivers. Even though they are more complex, the result is far superior.
However a simple TRF set can be made with the Radio IC and a few stages of audio amplification.

The following circuit uses just the Radio IC and a crystal earpiece or the home-made earpiece described above:
You can use a home-made FRAME ANTENNA or a home-made FERRITE ROD ANTENNA and a home-made VARIABLE CAPACITOR.

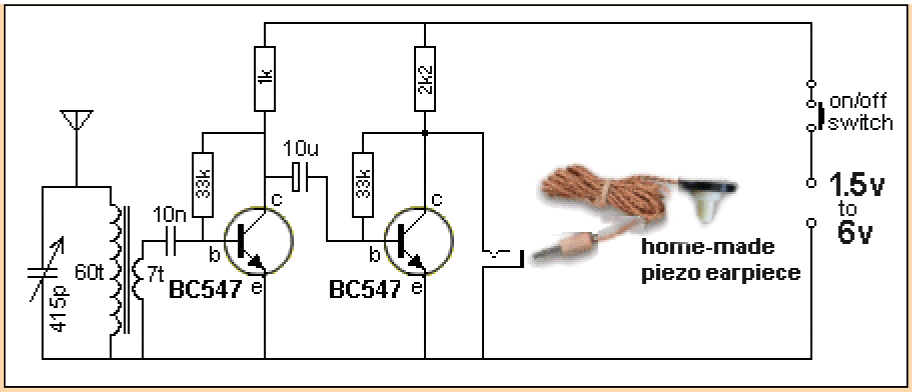


The Simplest ZN414 Radio

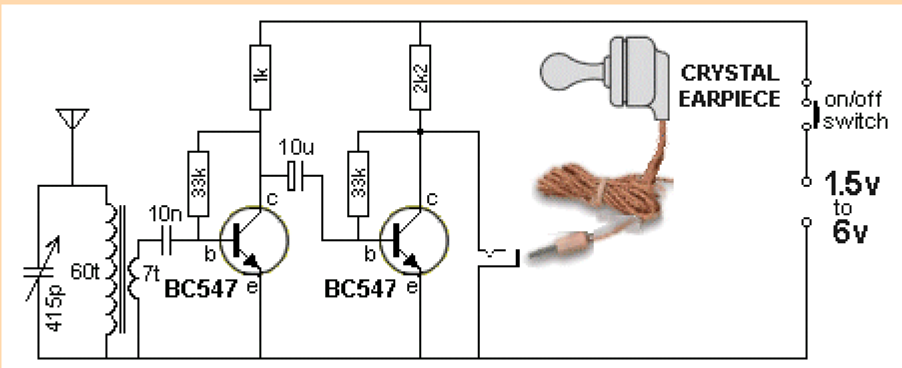
Connecting the ground (0v rail) to the frame of your soldering iron or a water tap will increase the output volume. The circuit above shows a Crystal Earpiece. Using a Crystal Earpiece may require adding a 10n across the earpiece to improve the output volume. The substitute Piezo Earpiece is effectively a 20n capacitor and an additional capacitor is not needed.

2 TRANSISTOR RADIO

Here is a simple 2-Transistor radio.
The secret to its performance is the 7 turn "pick-off" from the FRONT END (the TUNED CIRCUIT).
The ratio of 7 turns to 60 turns means a small percentage of the voltage generated in the tuned circuit is passed to the transistor. Thus it puts a small load on the TUNED CIRCUIT.
I don't want to go into any mathematics. The turns ratio is 60:7 = 8 but the effect of the 7 turns "pick-off" has an effect called the IMPEDANCE EFFECT and this is the SQUARE OF THE TURNS RATIO. Thus the IMPEDANCE EFFECT is 8 x 8 = 64. This means the "pick-off" (the LOADING EFFECT) is just a few percent. The front end can produce voltages as high as 500mV because a crystal set can produce a voltage high enough to pass through a diode (350mV) and have sufficient to drive a crystal earpiece.
Even though the front end has a "step-down" ratio, the voltage out the 7 turns will be sufficient to drive the first transistor.
The "transformer" does 2 things: It reduces the loading on the tuned circuit ENORMOUSLY and it produces an output with a higher current than is circuiting in the front end. Even though the transistor is turned ON and biased by the 33k, it is classified as a low-impedance load as far as the front end is concerned and the input signal has to be accompanied by a certain amount of current, otherwise the transistor will not respond to the voltage. The 7-turn "pick-off" is able to provide this current.
Both transistors are biased ON via the 33k base-bias resistors and thus the first transistor responds to the slightest millivolt signal.
This circuit was tested and had the same performance as the **Simplest ZN414 Radio Circuit** above. It can be operated on 1.5v to 6v and the strongest stations tend to overload on 6v. A short antenna is needed.



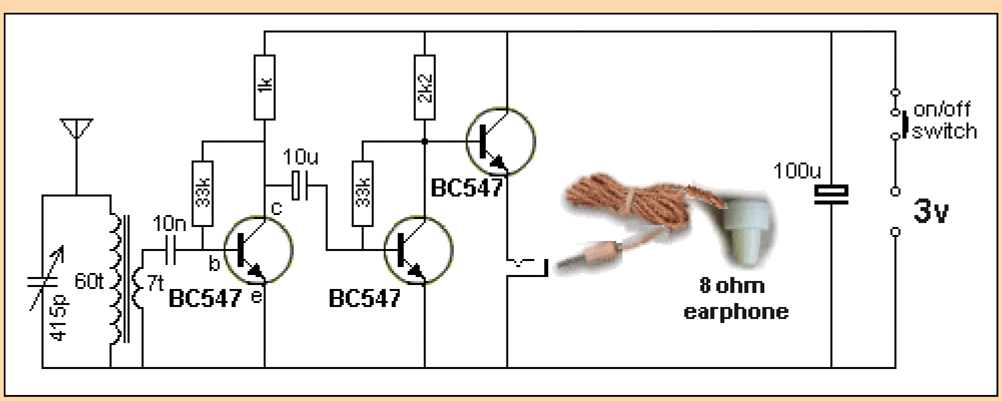
SIMPLEST 2-TRANSISTOR RADIO
using a very-high-impedance earpiece



SIMPLEST 2-TRANSISTOR RADIO
using a crystal earpiece

ADDING AN IMPEDANCE MATCHING STAGE

You can add an IMPEDANCE MATCHING STAGE to the output of the circuit above so a low-impedance earpiece can be used.
We call it an IMPEDANCE MATCHING STAGE because this is the correct technical term. It is an AMPLIFYING stage but it amplifies the CURRENT because the second transistor cannot drive an 8 ohm LOAD. 8 ohms is a very low resistance and if it is connected directly to the second transistor, the output will be almost zero.
The reason for this is covered in our discussion: [The Transistor Amplifier](#).
This stage will not increase the volume but simply match the 8 ohm load to the circuit above.
It is very difficult to connect a LOAD to this type of circuit because it will take more current from the battery and cause the supply voltage to fluctuate. These fluctuations will be passed to the first stage and cause variations in the signal. This will be amplified by the first and second transistors in the form of a low-frequency buzzing called **MOTOR-BOATING**.
The only way to reduce or remove this noise is to add an electrolytic across the power rails and reduce the supply voltage. The third transistor simply takes the waveform on the output of the second transistor and delivers it to the earphone with a higher current. It is called an IMPEDANCE MATCHING STAGE as it effectively increases the 8 ohm load by a factor of about 100.



3-TRANSISTOR RADIO with buffer stage for 8 ohm earpiece

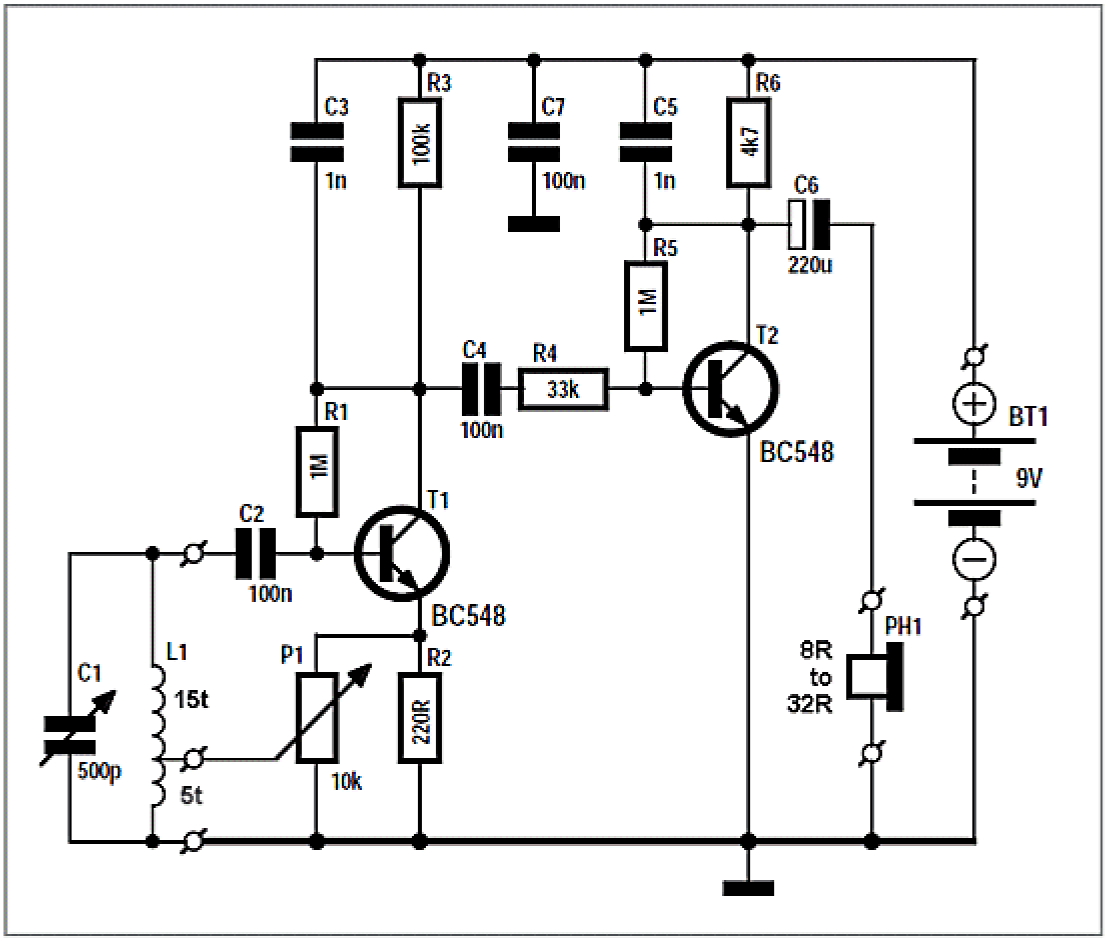
The 3rd transistor converts the 8R to about 800R

You can use 16 ohm, 32 ohm or 64 ohm in place of the 8R earpiece and these will give better performance as they will take less current and improve the stability of the circuit.
Low-impedance earphones create "motor-boating" due to the peaks of current and this can be very hard to fix.

A 2-TRANSISTOR RADIO with REGENERATION

The next stage in our discussion to get better performance is a feature called **REGENERATION**.
Regeneration sends a small output signal back to a previous stage in the form of POSITIVE FEEDBACK to INCREASE the original signal. The signal on the emitter of the first transistor is the same amplitude as the signal entering the base but the FRAME ANTENNA has a turns ratio of 5:15 and this increases the signal on the receiving section of the antenna by up to 3 times. But we want the returning signal to be just above the amplitude of the receiving signal and so a resistive adjustment (attenuator) is provided on the emitter to deliver just the right amplitude.
This has the effect of increasing the amplitude on the TUNED CIRCUIT and is just like reducing the load on the circuit.
As we have mentioned above, when the tuned circuit is lightly loaded, it will pick up a station at the exact frequency of transmission and if the dial is changed slightly, the station will disappear. This quality is called SELECTIVITY.
At the same time, the Tuned Circuit will pick up weak stations and this is called SENSITIVITY.
The quality of a receiver depends on the loading of the TUNED CIRCUIT.

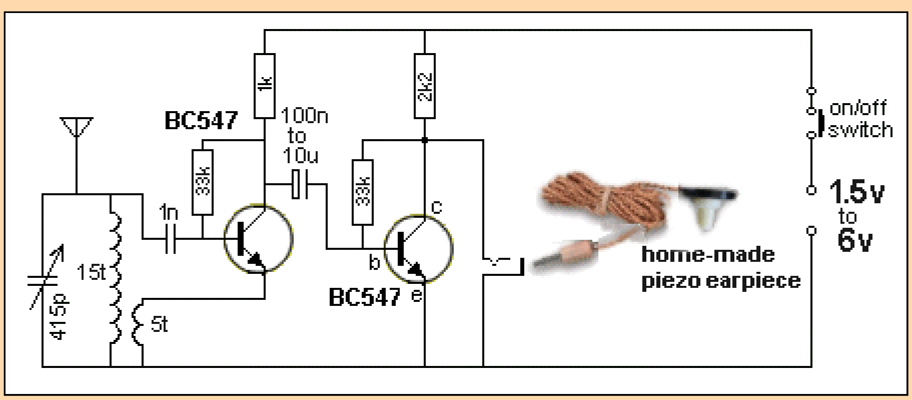
Here is the original circuit from Elektor Magazine with the prototype made on matrix board and fixed to a base-board with a frame antenna made from two sticks of wood. The photo shows a speaker but the output is so low that you really need headphones.



2 TRANSISTOR REGENERATIVE RADIO from Elektor Magazine

The circuit is very complex and the output will be very low as the circuit cannot drive a low-impedance earphone via a 4k7 load resistor. The 4k7 resistor is actually driving the speaker (the transistor is simply discharging the 220u). The 4k7 only allows 32/4700 x 9 = 61mV to appear across the earphone - a very poor result.
The skill of designing a transistor stage is covered in our comprehensive eBook: [The Transistor Amplifier] and you wont make a mistake like this !!!
The circuit above can be simplified and we can add the REGENERATIVE feature to our **Simplest 2-Transistor Radio** circuit:

Our circuit uses a 15 turn circular FRAME ANTENNA 15cm diameter and a 5 turn REGENERATION coil.



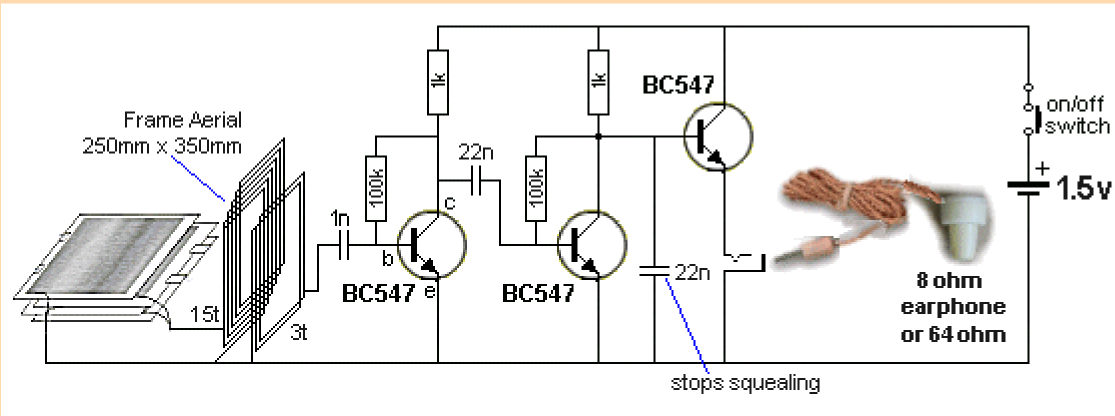
2 TRANSISTOR RADIO with REGENERATION

The regeneration coil is brought near the main coil and as it gets closer you can hear the audio get louder. If this does not happen, turn the coil around.
Early radios used this technique and the operator had to adjust the coil by hand. No-one minded because radio was a fascination and the simplest radio cost more than a weeks wages. To listen

to a broadcast through headphones was an amazement and listeners would sit all night with headphones listening to music.
This is very fiddly and by adding an extra buffer stage, we can use a Frame Antenna with a very clever "pick-off" that does not load the front end. This gives the circuit very good sensitivity and selectivity without regeneration.

3 TRANSISTOR RADIO

Here is our final design for the simplest self-contained 3-Transistor Radio using our home-made Tuning Capacitor and 250mm x 350mm Frame Antenna. It picks up the local stations and drives a low-impedance earphone or set of earphones (from a mobile phone).



3-TRANSISTOR RADIO

The circuit performs very well and uses readily-available components. The 22n across the output is essential to stop squealing.
The secret to sensitivity and selectivity is the turns-ratio on the Frame Antenna. The 3-turn "pick-off" puts very little load on the front end and this allows the stations to be tuned with our home-made Tuning Capacitor.
The circuit contains all the features we have discussed above and only needs a 1.5v supply.
Build this circuit before you buy any expensive tuning capacitors, IC's or ferrite slab antennas as you will not get any better results.
This is called a TRF circuit and because the stages operate at Radio Frequency or Audio Frequency. Due to the high amount of amplification, the circuit can start to squeal (feedback, motorboat) due to the layout.
You may need to shorten or lengthen the leads or move the parts slightly - it's that critical.
However the result is a portable radio that needs no earth and will pick up the strong stations.
You can try connecting the 0v rail to the metal part of a soldering iron to increase the number of stations.

LOADING

The whole success of picking up a radio station is the RECEIVING CIRCUIT. The receiving circuit is the coil and the signal in the air (from the radio station) must go down the centre of the coil.
It cannot pass over the top or the bottom of the coil. Only the signal that goes down the centre of the coil is received.
As you can see, the centre of the coil is not very big and it is amazing that the signal can pass down the centre. But it does, and that is the only signal that will be amplified.
This signal is passed to the capacitor and we have explained how the signal is gradually increased and increased in amplitude until it is as large as 500mV. The signal from the radio station may be as small as a few millivolts, but as it keeps pushing the "swing" back and forth, the amplitude get larger and larger.
If you put your finger on the "swing" you will prevent it get larger and larger and it only requires the slightest touch of your finger to prevent the swing gaining full amplitude.
In electronic terms, your finger is called LOADING THE CIRCUIT and since we have to pass the signal to further stages of amplification, we need to "tap" or "load" or "pick-off" a signal.
The aim is to load the circuit as least as possible because the actual energy entering the circuit is very small.
In fact, this is all the energy we can remove as that is all the energy entering it.
Because a very small amount of energy is entering the "front-end" we classify it having a very

high impedance. It is very difficult to provide a value of impedance for this circuit because impedance has the term "Z" and the circuit is operating a very high frequency so resistance values are not the same as impedance values.
The actual resistance of the circuit is ONE OHM but the impedance is more like 10,000 ohms to 100,000 ohms.
We can explain its high impedance if we put a 100,000 ohm resistor across the circuit. The waveform will be reduced very slightly. If we put a 10,000 ohm resistor across the circuit, the signal will be reduced a reasonably large amount. If we put 1,000 ohms across the circuit it will stop working.
This means a load of 100,000 ohms will have the least effect.
In a crystal set, the diode creates NO LOAD until a voltage of 350mV is reached. It then passes excess voltage to a crystal earpiece that has a very high impedance. That's why a crystal set will produce a good output. The LOADING is very small.
When a transistor is connected to the TUNED CIRCUIT, it starts to put a load on the circuit after 600mV and this load is VERY HIGH. The "resistance" of the base-emitter junction is about 1k and the signal will find it very difficult to rise above 600mV because the incoming energy is not sufficient to increase the voltage.
Adding a capacitor between the base and the front end allows the transistor to be self-biased and get a turn-on voltage of about 600mV from a base-bias resistor.
The FRONT END is now separated from the transistor and ANY voltage it is producing will be passed to the transistor via the capacitor.
Whereas, with the crystal set, the first 350mV could be produced without any loading, the circuit is now loaded AT ALL TIMES.
This means we have to load the circuit as lightly as possible to be able to pick up individual stations.
The only way we can do this is to use a capacitor of the smallest practical value and this has to be worked out by trying different values. If the value is too small, the transistor will not detect a small signal. If the value is too large, the circuit will stop working.
Values such as 1n, 10n and 100n are suitable.
Values such as 1u, or 10u will be too large.
The CRYSTAL SET loading and a transistor load are completely different.
The transistor loads the front end ALL THE TIME and that's why you need to use a transformer or other ways to reduce the loading. Sometimes a Field Effect Transistor is used as it puts almost no load on the front end.

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HOW A DIODE WORKS

incl zener diodes

(a Self-teaching Guide)

DIODE TEST

see also:

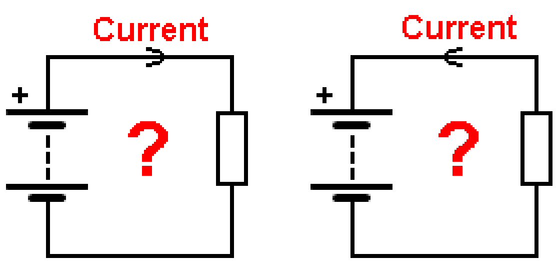
How a Capacitor Works

Home

More on the diode in: Basic Electronics 1A

There is a lot of confusion in text books and on the web about CURRENT FLOW.

WHICH WAY DOES CURRENT FLOW?



Current is a flow of electrons. These electrons are negatively charged particles and they are attracted to the POSITIVE of the supply. This means they flow from NEGATIVE to POSITIVE.
The first inventors and discoverers of electricity did not know this.
They thought electricity flowed from POSITIVE to NEGATIVE.
So, they made a CONVENTION (statement) that electricity (CURRENT) flows from POSITIVE to NEGATIVE.

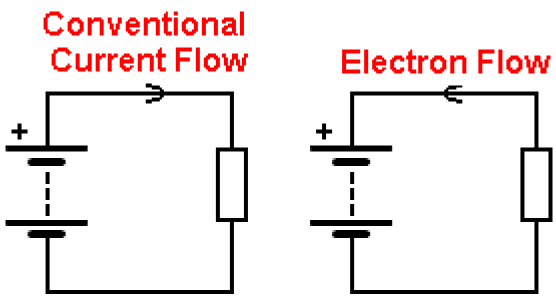
They were wrong. But hundreds of text books had already been written, so we have TWO situations.

The answer is simple.
When we discuss electrical and electronic circuits, we use the old convention, called **CONVENTIONAL CURRENT FLOW** (from positive to negative). To get away from any idea of thinking about "electrons" we say "**electricity flows from positive to negative**." We say this so we can follow all the electrical and electronic circuits using arrows that point in the direction of CONVENTIONAL CURRENT FLOW.

When discussing **ELECTRON-FLOW** we use NEGATIVE to POSITIVE.

We keep ELECTRON FLOW arrows within the component we are talking about (such as a radio-valve or transistor-model) and do not put electron-flow arrows on the rest of the circuit.
We have to do this to prevent CONFUSION.

Here is the answer:



The Electron Flow arrow should be within the component and NOT on the wiring

Don't use any text-books that say current flow is electron-flow as they are omitting **CONVENTIONAL CURRENT FLOW** and this will confuse you.

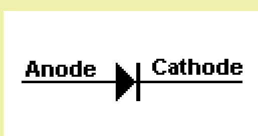
We are discussing this point because a diode is an ELECTRONIC device. In other words it involves the flow of electrons because CURRENT will only flow in one direction through a diode.
In all of our discussions we have used **CONVENTIONAL CURRENT FLOW** as we are talking to **beginners in electronics** and not PHYSICS students.
Some text books use one convention, then the other convention and nothing can be followed.
Note: the arrow on the emitter of a transistor follows conventional current flow, even though electron flow was known at the time.

A diode is a very simple device and it has a lot of applications. We will cover some of its uses and explain exactly how it works **in very simple terms**.
If you don't understand any of the points in this discussion, you can contact Colin Mitchell.

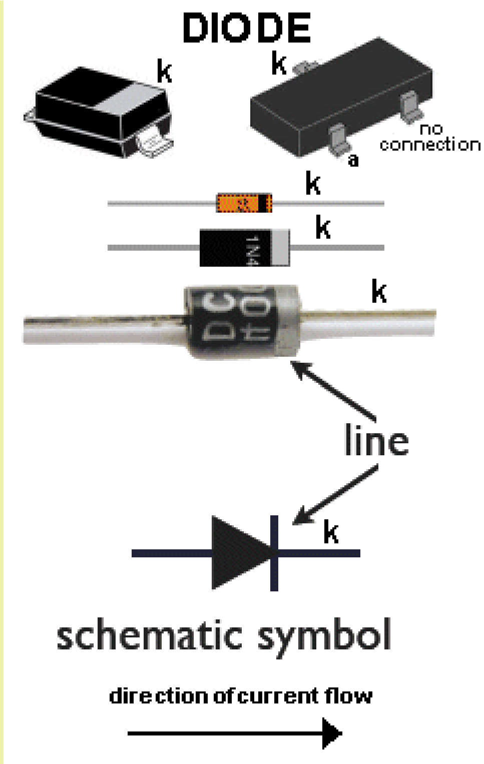
A diode is a device that passes current in only one direction. It is a bit like a water-valve that prevents water back-flowing into the mains from your property. Or a valve in a pump that prevents the water flowing back down a well.

There are many types of diodes to handle small currents, large currents, high frequencies and high voltages. And there are diodes made from different materials, but they can all be described in a simple way. And that's what we will do.

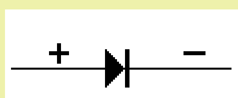
A diode has two leads. These are called ANODE and CATHODE.



The cathode end is identified in a circuit diagram and on the body of the device.
It may be identified with a line, chamfer or dimple or a symbol. There must be something on the diode that identifies this lead and you have to look for it.

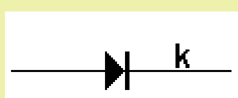


A diode does NOT have a positive or negative end. You see this mistake in so many discussions. A diode will have a positive voltage on the anode and a slightly lower (positive) voltage on the cathode. It will not have a positive on the anode and negative on the cathode.



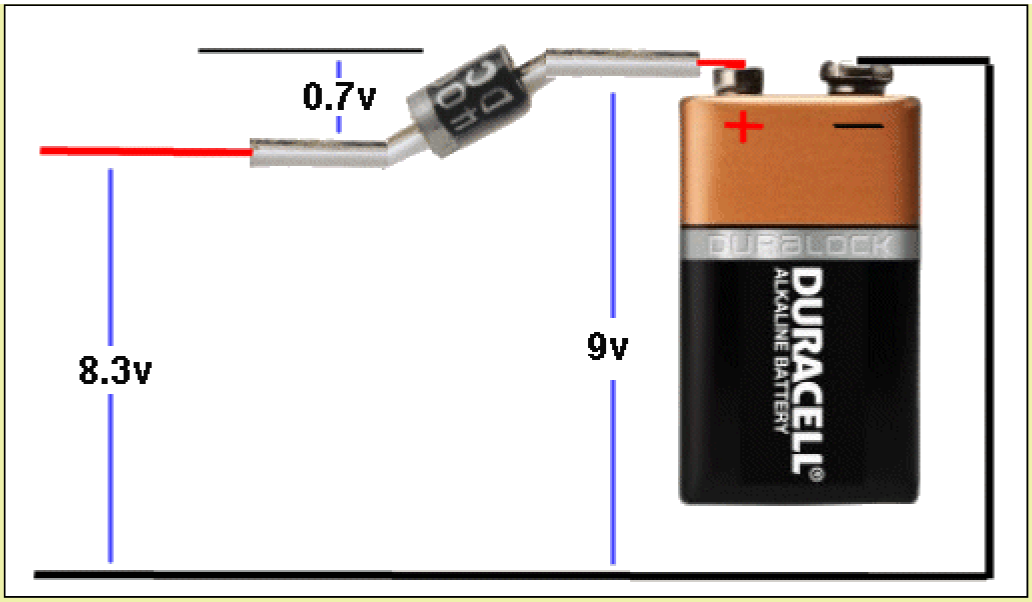
Incorrect marking with "+" and "-"

In the following diagram only the CATHODE is identified with the letter **k** (for kathode). The other lead is the ANODE.

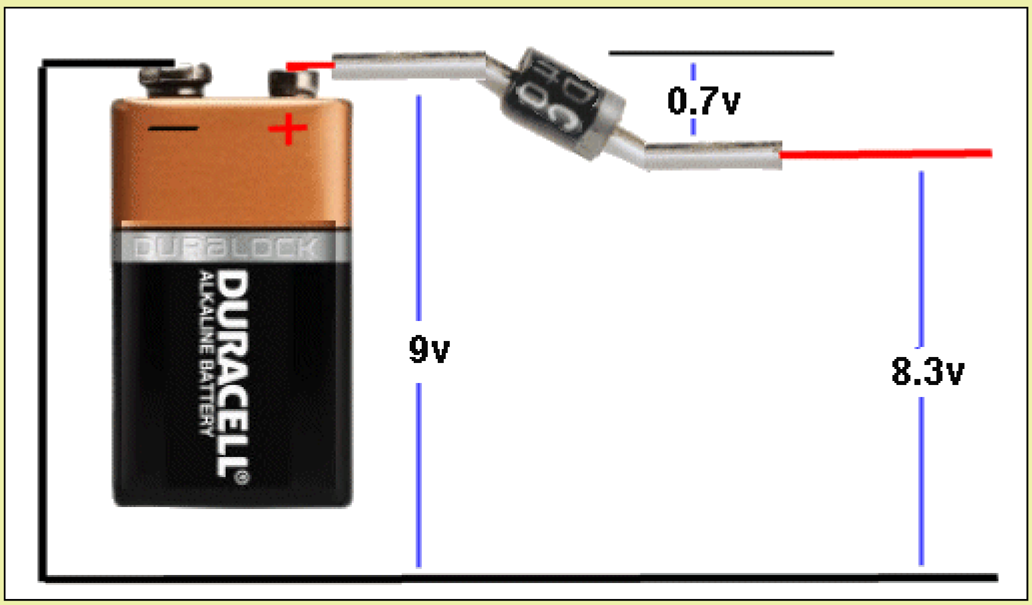


Correct marking with "k"

Here is a pictorial way to understand how a diode works:



OR



IT DOES NOT MATTER WHICH WAY YOU DRAW THE CIRCUIT, THE RESULT IS THE SAME

9v comes out of the battery and when it passes through the diode, 07v is LOST (dropped across the diode), resulting in 8.3v available to operate a motor etc.

The most common type of diode is made from SILICON. It can also be made from GERMANIUM. You need to look in the datasheet to find the composition of the diode you are using.

As mentioned above, a diode does not start to TURN ON until a small voltage is present on its ANODE lead.
For a Germanium diode, this voltage is approx 0.3v.
For a Schottkey diode, this voltage is 0.3v
For a Silicon diode, this voltage is 0.7v. As the current increases, this voltage can rise to about 1.1v (at full current-flow for the diode).

Question

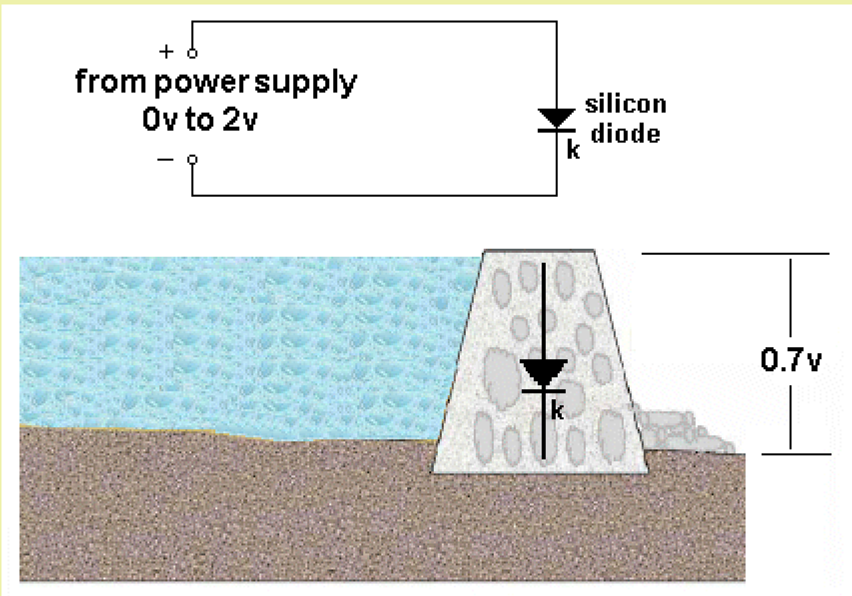
For a diode, does current flow from anode to cathode, or cathode to anode?

Answer

Current flows from anode to cathode. The arrow on the symbol shows the direction of **CONVENTIONAL CURRENT** flow.

WE WILL TAKE THE EXAMPLE OF A SILICON DIODE

A silicon diode is just like the wall of a dam. As soon as the water reaches the top of the wall, it overflows. The silicon diode has a height of 0.7v and as the voltage from the power supply increases, nothing happens until the voltage reaches 0.7v. At this voltage CURRENT STARTS TO FLOW and if the voltage is increased, the CURRENT INCREASES and the diode is destroyed. It's just like all the water flowing over the top of the dam.



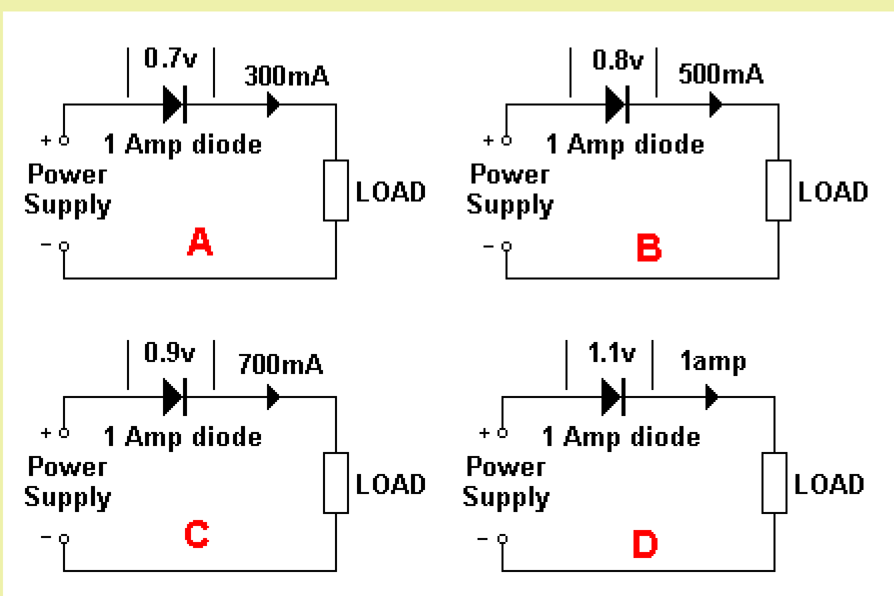
DIODE VOLTAGE NOT CONSTANT

We have said the voltage across a silicon diode is 0.7v. This voltage increases slightly as the current increases.

For a 1 amp diode, this voltage will increase to about 1.1v when 1 amp is flowing.

For a 3 amp diode, this voltage will increase to about 1.1v when 3amp is flowing.

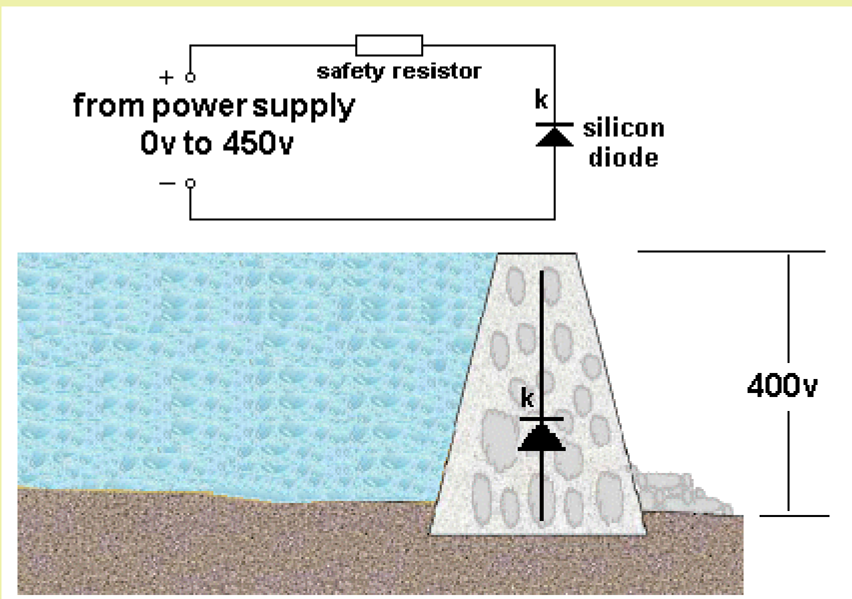
For a 10 amp diode, this voltage will increase to about 1.1v when 10 amp is flowing.



The voltage across a diode increases with current-flow

In the diagrams above, the current-flow is determined by the voltage of the Power Supply **AND** the current required by the load. The diode does **NOT** determine the current-flow. By increasing the voltage of the Power Supply, the current will increase.
The LOAD can be a motor, globe or high-wattage resistor.
In diagram **A**, the voltage drop (voltage lost) across the diode is 0.7v. This voltage increases to 1.1v in diagram **D** due to the **increase in current**.
Because the current **and** voltage increases in each diagram, the wattage (heat generated) by the diode increases at a very fast rate:
In diagram **A** the wattage generated by the diode is: 0.3 x 0.7 = 0.21watts
In diagram **B** the wattage generated by the diode is: 0.5 x 0.8 = 0.4watts
In diagram **C** the wattage generated by the diode is: 0.7 x 0.9 = 0.63watts
In diagram **D** the wattage generated by the diode is: 1.1 x 1 = 1.1watts

REVERSE VOLTAGE
If you connect a diode around the wrong way, no current will flow. But if you increase the voltage to 100v, 200v or 300v, the diode will suddenly break-down and a large current will flow.
The voltage at which this occurs is called the REVERSE BREAKDOWN VOLTAGE.
It could be as low as a few volts or as high as 1,000v.
This voltage is always provided in the data sheet as it is most-important.
If a diode is used in a mains BRIDGE RECTIFIER (to be discussed later), it will see a voltage as high as 325v for the 240v mains and the diode will need to be a 400v device.



A 1N4004 is a 400v diode - This is its REVERSE VOLTAGE rating

In the circuit above, the diode will not be destroyed when the voltage reaches 400v (for a 1N4004) because the current-limiting SAFETY RESISTOR has been included.

Question
For a silicon diode, what is the approximate voltage-drop across its leads when it is delivering about 10% of its rated current?

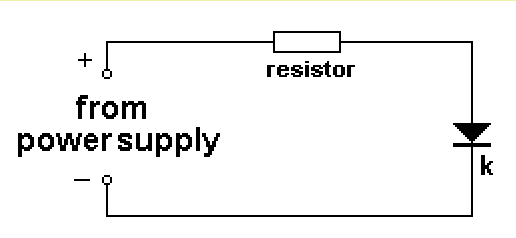
Answer
0.7v This is is the voltage we use for current up to about 40% of maximum current.

Question
Which lead of a silicon diode is identified on a circuit diagram?

Answer
The cathode lead is identified with the letter "k"

Question

In the following diagram, is the diode conducting?

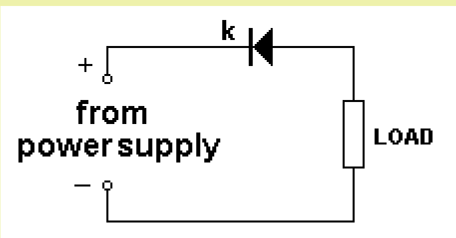


Answer

Yes

Question

In the following diagram, is the diode conducting?

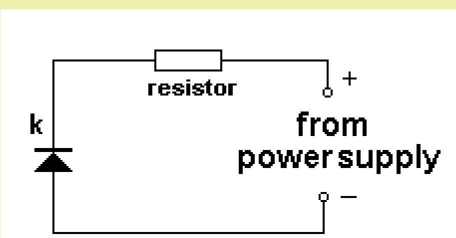


Answer

No. The diode is reverse-biased. The arrow on the diode indicates the direction of current-flow.

Question

In the following diagram, is the diode conducting?

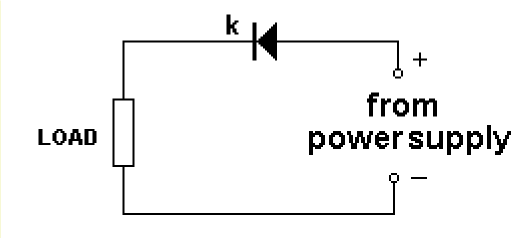


Answer

No. The diode is reverse-biased. The arrow on the diode indicates the direction of current-flow.

Question

In the following diagram, is the diode conducting?

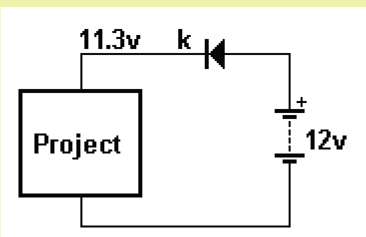


Answer
Yes

DIODE APPLICATIONS
Here are some applications for a diode (or set of diodes):

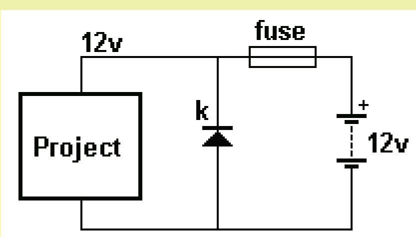
THE DIODE AS A PROTECTION DIODE

In the following diagram, the diode does not conduct if the battery is connected around the wrong way. It is called a **PROTECTION DIODE**. This means the circuit will not see a reverse voltage and will not be damaged.
However the circuit will see a voltage 0.7v less than the voltage of the battery due to the 0.7v drop (lost) across the diode.



Protection diode

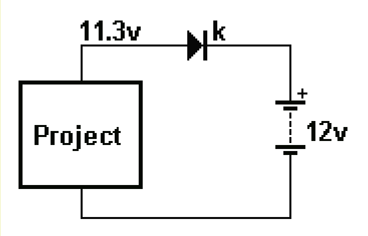
In the following circuit, the diode conducts if the battery is connected around the wrong way and creates a **SHORT-CIRCUIT**. This will burn-out the fuse. The diode is called a **PROTECTION DIODE**.



Protection diode

The advantage of this circuit is the diode does not drop 0.7v between the supply and the voltage on the project. The full voltage of the supply is connected directly to the project. This is a big advantage for projects working on 12v (battery) and require a high current, however the fuse will be damaged if the battery is connected around the wrong way.

Question
In the following diagram, describe the fault:



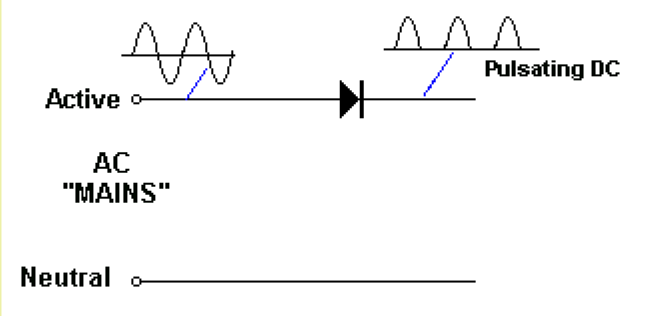
Answer

The diode has been drawn around the wrong way.

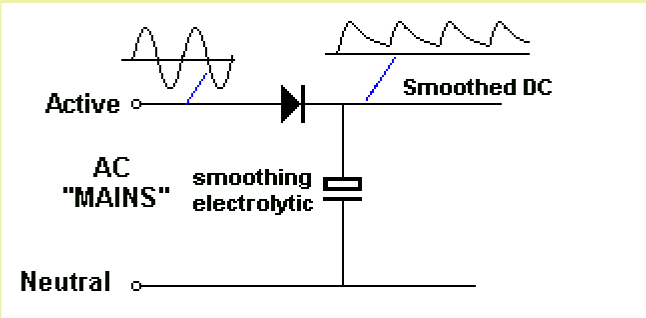
THE DIODE CONVERTS AC TO DC

A diode can be used to convert AC to DC:
The diode converts AC (called ALTERNATING CURRENT) to DC (called DIRECT CURRENT).
The original household voltage was 120v DC (direct current). DC is the same type of voltage that comes from a battery. It does not rise and fall but is steady at the specified voltage.
If you apply 120v DC to a 120v globe, it illuminates brightly.
You can also operate motors, toasters, heaters and other simple pieces of equipment from DC. (But you cannot operate a piece of equipment containing a transformer and that's why it has such limited use.)
And you need to locate the generator very close to each household because you cannot use transformers to deliver the supply and there is a voltage drop in the street wiring due to the current flowing in the wiring.
This needed lots of small generating plants and it was a very expensive way to deliver electricity.
The solution was to convert to AC (alternating current) and locate a single generating plant at either a source of coal or water for hydro electricity.
But since AC is rising and falling, the heat produced by 120v AC in a toaster (for example) will not be as much as 120v DC because part of the waveform is less than 120v for a portion of the cycle.
The answer was to make the 120v AC rise higher than 120v for part of the cycle so that it produced the same heat as 120v DC.
This means the 120v AC rises to 170v at its peak.
For 240v AC mains, the voltage rises to 336v.
That's why the 120v or 240v mains is so dangerous. Your body actually detects the 336v and this is what kills you.
Now, let's understand how this 120v/240v is delivered.
The mains actually consists of a single wire. This is called the ACTIVE.
The other wire is the GROUND or EARTH or NEUTRAL.
Sometimes the Neutral is also delivered as a wire, but let's take the case of a single ACTIVE wire.
The voltage in the active wire is rising 336v HIGHER than earth then it falls to 336v LOWER than earth. It is rising and falling like this 50 or 60 times per second.
Once you understand this concept, you will able to see how a diode converts AC to DC.

Placing a diode on the active line of the mains will remove the part of the waveform that falls 336v LOWER than earth.
The result is a set of 50 or 60 pulses per second that rise 336v higher than earth. In actual fact a pulse rises 336v then falls to zero. There is no waveform during the time when the original waveform falls below earth.
The following diagram shows the result of adding a diode to the active line. The result is not DC but PULSATING DC and needs to be smoothed via an electrolytic to get DC.



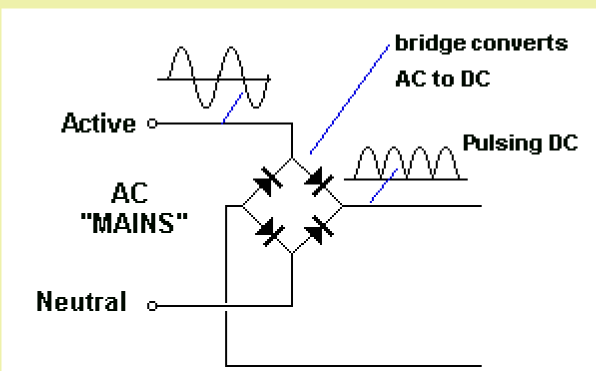
The following diagram shows the result of adding an electrolytic:



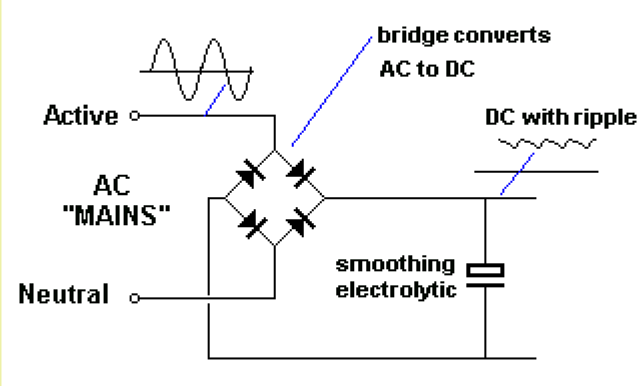
Using a single diode is called **HALF-WAVE RECTIFICATION**.
Adding an electrolytic is called **SMOOTHING**. It can also be called **REDUCING THE RIPPLE**.

FULL WAVE RECTIFICATION

The negative portions of an AC waveform can be combined with the positive portions to produce a pulsing DC waveform.
See: http://www.electronics-tutorials.ws/diode/diode_6.html
or:
http://www.eecs.tufts.edu/~dsculley/tutorial/diodes/diodes3.html
for an explanation on how the diodes in the bridge "guide" the incoming waveform to produce pulsing DC:

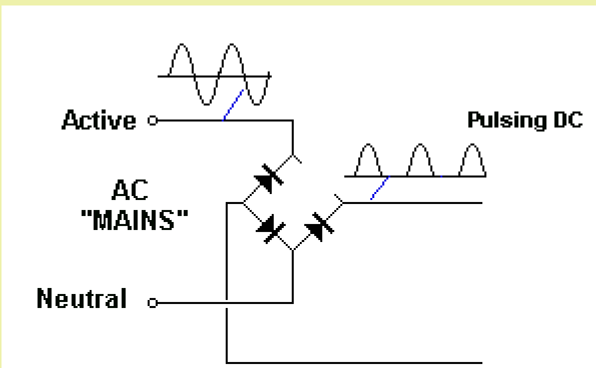


When an electrolytic is added to the circuit, it charges during the peaks and delivers energy when the waveform drops. The result is called **DC with Ripple**.

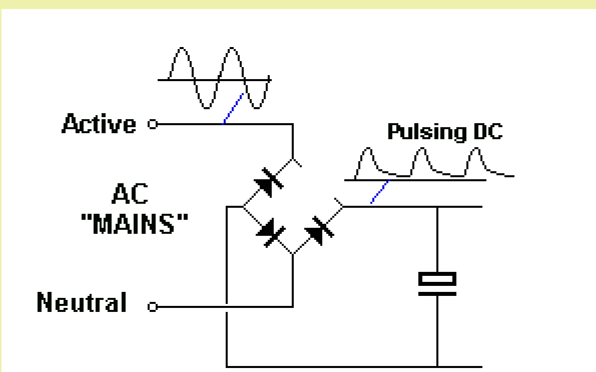


What happens when a diode goes "OPEN?"

The output consists of peaks and spaces:



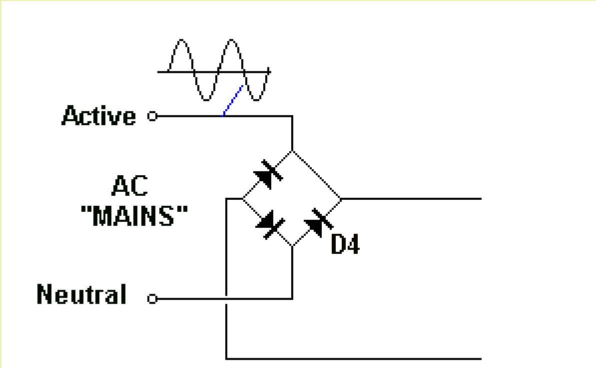
When an electrolytic is added, the output voltage looks something like the following, depending on the value of the electrolytic and the current taken by the load. The audio will have a distinct 50Hz hum or "buzz."



What will actually happen is the positive rail will still remain positive but it will be very close to the voltage of the neutral input and the 0v of the supply will be LOWER THAN THE NEUTRAL RAIL.
In other words, the output voltage will "shift down" (relative to the input waveform) but because the output voltage is considered as a "floating voltage" you will not be aware of this.
This fault highlights the dangers in producing a power supply without a transformer.
Normally, the power supply will have the 0v rail connected to components and maybe the chassis or metal case of the project because the 0v rail will be very close to the voltage on the NEUTRAL and this will be very close to "GROUND." But if a diode goes open, the chassis immediately sees the voltage of the ACTIVE and this can produce an electrical shock.

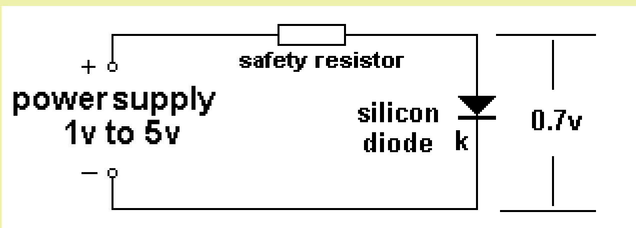
What happens when a diode goes "SHORT-CIRCUIT?"

When the active line is positive, the full voltage of the mains appears on the output. But when the mains voltage reverses, the "Neutral" is positive and the voltage passes through Diode D4, DIRECTLY to the active line and this creates a SHORT-CIRCUIT. The current through D4 will be very high and it will be damaged.



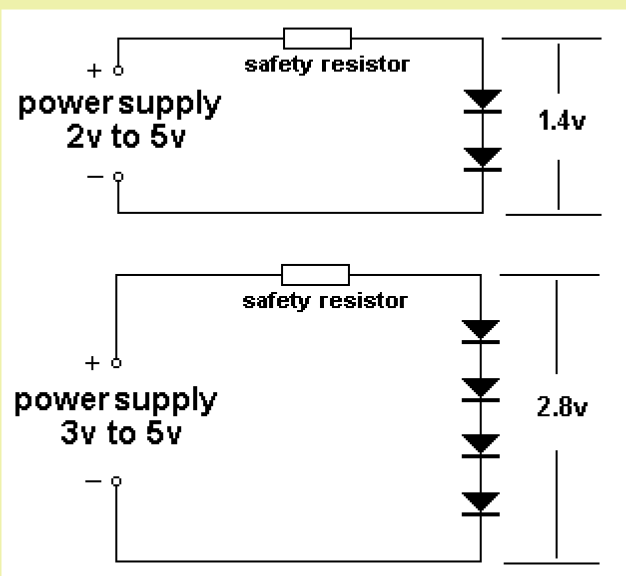
USING A DIODE AS A VOLTAGE REFERENCE

In the following diagram we see a silicon diode connected to a power supply via a safety resistor:



The power supply is adjusted from 1v to 5v and the voltage across the diode remains constant at 0.7v.

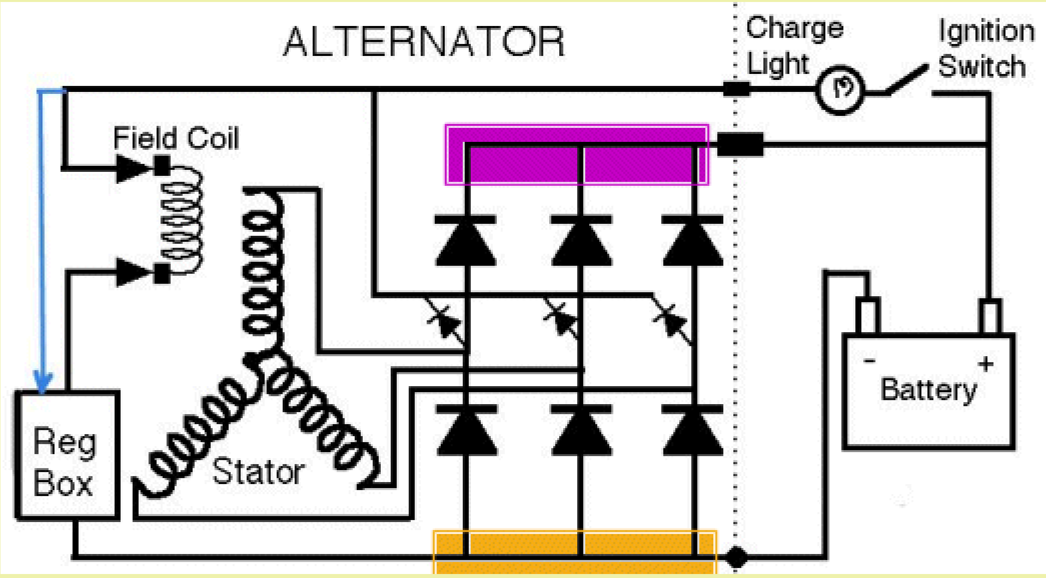
We can place two or more diodes in series to increase the output voltage:



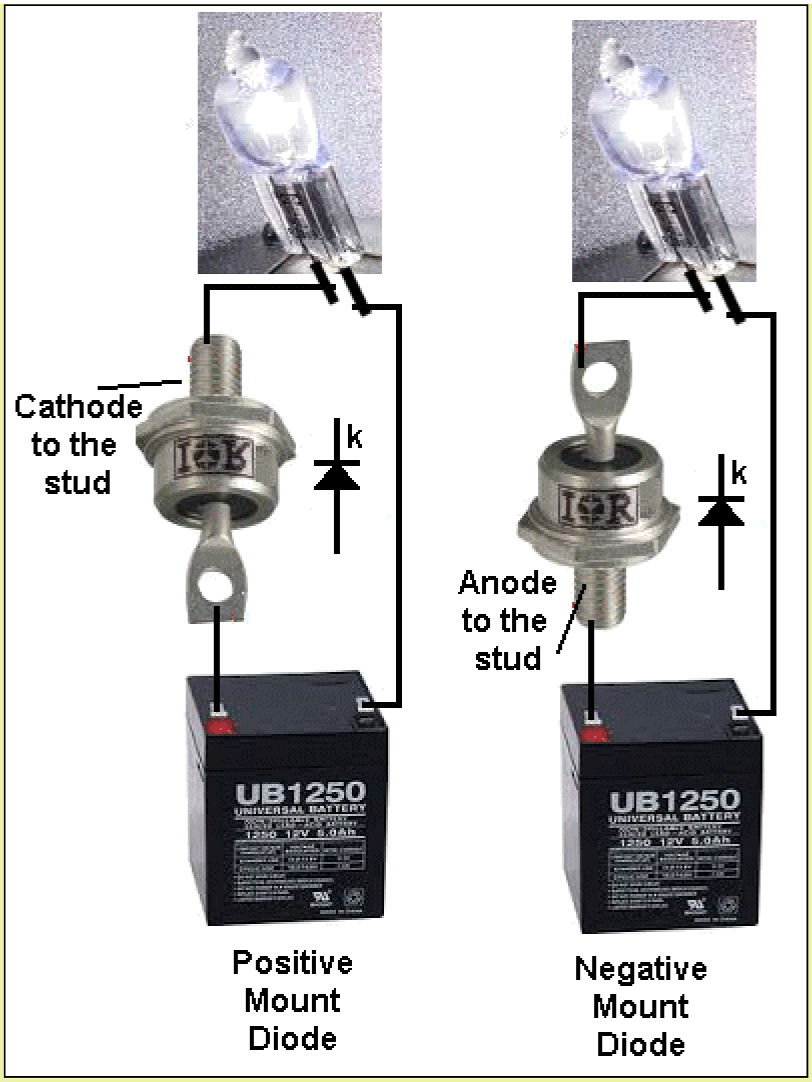
POSITIVE AND NEGATIVE STUD MOUNT DIODES

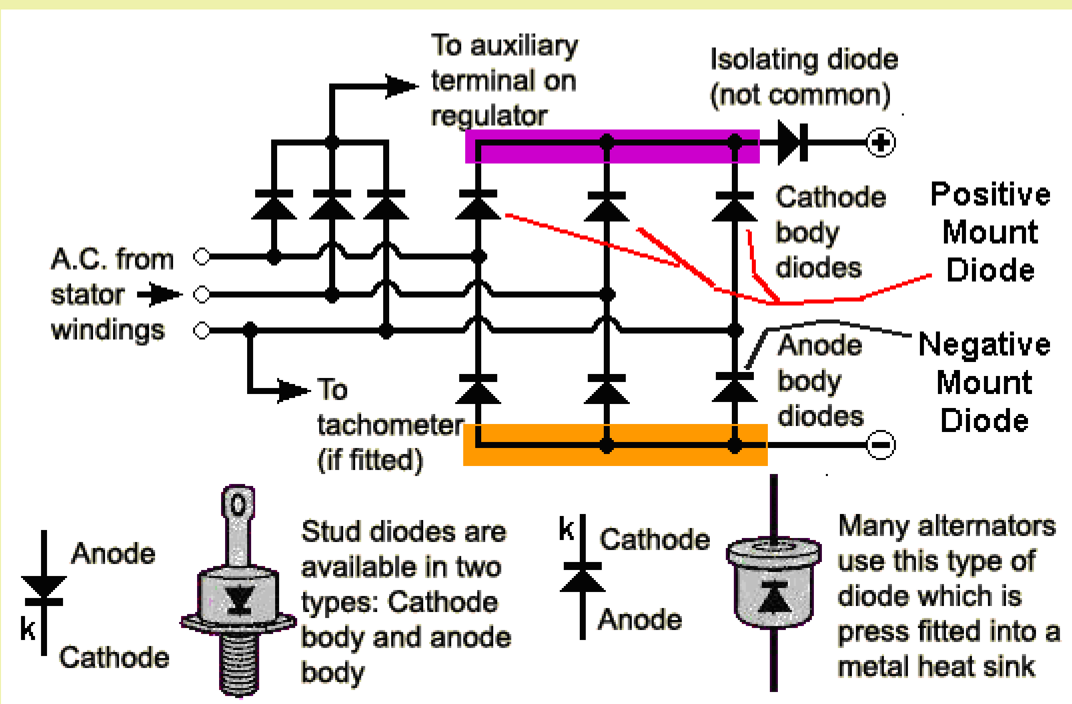
There is no such thing as a "Positive or Negative" diode, but in car and truck alternators there are a number of diodes to convert the alternating voltage produced by the alternator to pulsing DC to charge the battery and operate the lighting system.
The battery then becomes a huge storing component to smooth the pulses to get a very smooth DC and that's why the lights don't flicker.
The alternator is actually a 3-phase generator as this will produce the maximum output during each revolution.
The three windings are connected to 6 diodes and these diodes are mounted on two plates that act as heatsinks.

Referring to the circuit below you can see the top 3 diodes are connected to the purple plate (heatsink) and the 3 lower diodes to the brown plate (heatsink).



The image above shows 3 diodes connected to a plate. They can be ALL positive-mount stud diodes or negative-mount.
Here is a diagram to find positive-mount diodes and negative-mount diodes:





This circuit show Positive-mount diodes at the top and Negative-mount diodes at the bottom

Negative Mount Diode
Anode Body

Positive Mount Diode
Cathode Body

You will notice that both diodes have the same part number and most stud diodes come in either "Stud Cathode" or "Stud Anode."
You need to make sure which version you are ordering BEFORE placing an order.
Some stud diodes have different colour potting (surrounding the lead) as shown in the following image:

A Positive Mount Stud Diode has the cathode connected to the STUD or "body" or screw-thread. This is called a "normal" diode.   This is not "electronic" terminology but only refers to stud diodes for alternators.
A reverse diode sometimes has "R" added to the numbering on the component.

The two heatsinks are insulated (isolated) from each other because one is connected to the positive of the battery and the other to the negative of the battery.

TESTING A STUD MOUNT DIODE

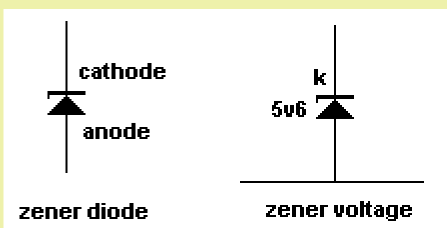
If you have no testing equipment, you can test a diode by connecting a car globe to 2 leads and connecting them to a battery. The globe will illuminate.
Now connect one of the leads to the battery via the diode. The globe will illuminate. Reverse the diode. The globe will not illuminate.
If it illuminates in both directions the diode is faulty (shorted). If the globe never illuminates, the diode is faulty (open).
You can do this will all the diodes on the heatsinks and compare a new diode with the others to make sure you are fitting the correct type of diode.
You MUST do this with every diode before you fit it as this is the only certain way to fit the correct diode. It is so easy to make a mistake.
You can use a multimeter but a globe will not allow a mistake to be made. You can "see" it working.

THE HEATSINK

The diodes must be mounted on a heatsink because each diode produces a voltage across it of about 0.7v to nearly 1v and when 10 to 20 amps is flowing each diode can produce heat equal to 10 watts. Adding up all the heat being lost can come to 60 watts and this is why the heatsinks get hot and why some of the diodes fail.
Each diode must be firmly attached to the heatsink to allow the heat produced by the diode to be passed to the heatsink.
Diodes cannot be operated "in the air" as they will get very hot and can fail due to overheating.
The only way to test the output of each diode is with a car globe.
You can use up to 100 watts as this will test each diode under load and identify a diode that tests ok with test equipment but fails when a high current flows.

THE ZENER DIODE

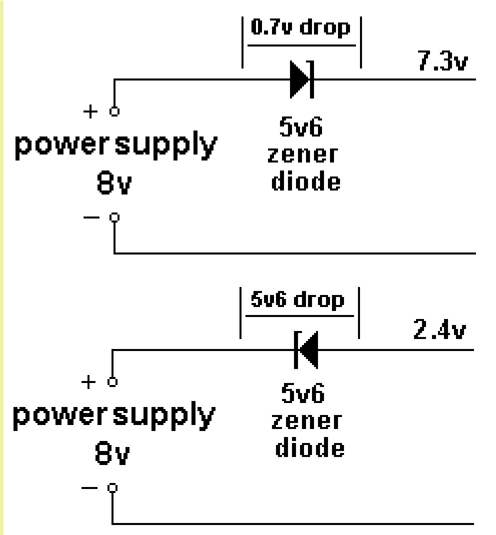
Zener diodes come in voltages from 3v3 to more than 47v. You can consider them to be ordinary diodes that have "failed." For instance a 1N4001 diode has a reverse breakdown voltage of 50v. **It is a 50v ZENER DIODE**.



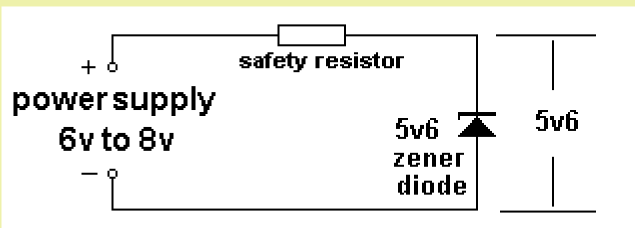
Zener Symbol and voltage

A zener diode should always be identified in a circuit with its voltage next to the symbol. You can include the wattage but this can be worked out by looking at the voltage and current flowing though the zener. Don't use part-numbers to identify the zener voltage as the reader will have to look-up a product-list to find the zener voltage. Circuit diagrams should be instantly readable and instantly understandable.

A zener diode drops 0.7v when connected around one way and drops its ZENER VOLTAGE when connected around the other way. Here is a diagram to show this:

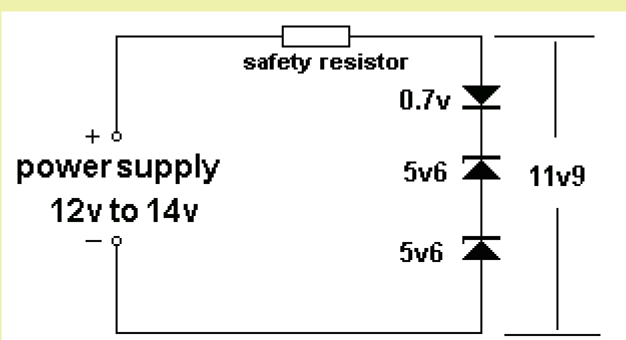


The following diagram shows a zener diode producing a constant 5v6 output when the power supply ranges from 6v to more than 8v.



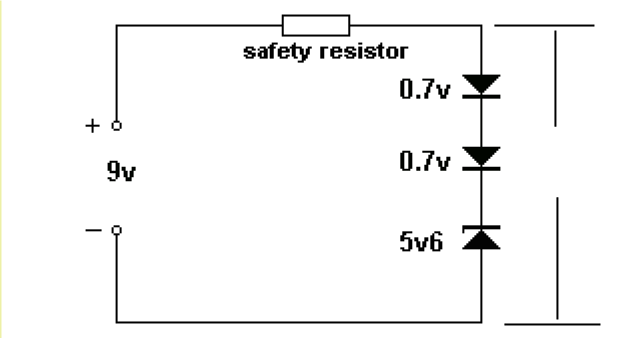
If the power supply is adjusted from 0v to 8v, no current flows in the circuit when the voltage is below 5v6. As soon as the power supply reaches 5v6, current flows through the safety resistor and the diode.
If the power supply voltage is increased, more current flows through the safety resistor and through the zener diode. The voltage across the leads of the zener diode remains a **constant 5v6.**
If the voltage of the power supply is increased further, the current through the zener diode will increase. It will get hotter and eventually burn out.

You can produce any zener reference voltage by combining zener diodes and ordinary diodes:



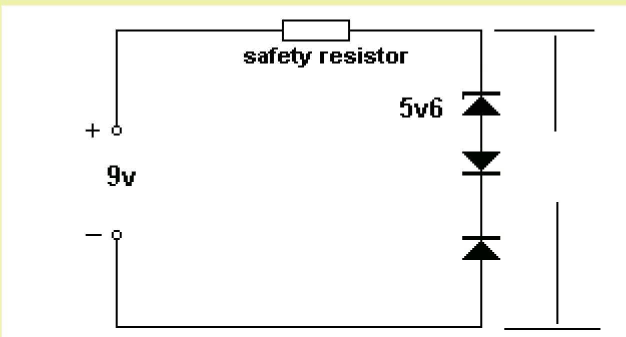
Notes:
You can see the two 5v6 zener diodes in the diagram above are connected around the **opposite way** to the ordinary diode.

Question
In the following diagram, what is the combined zener voltage?



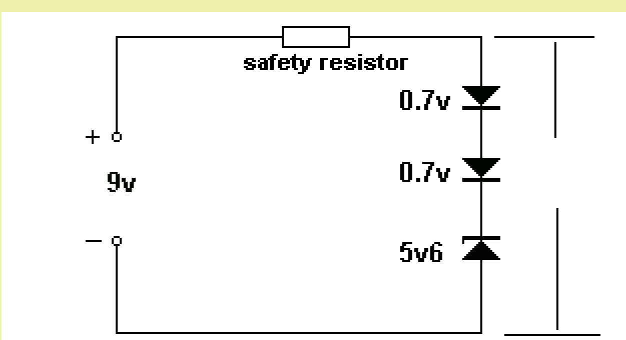
Answer
7v

Question
In the following diagram, what is the combined zener voltage?



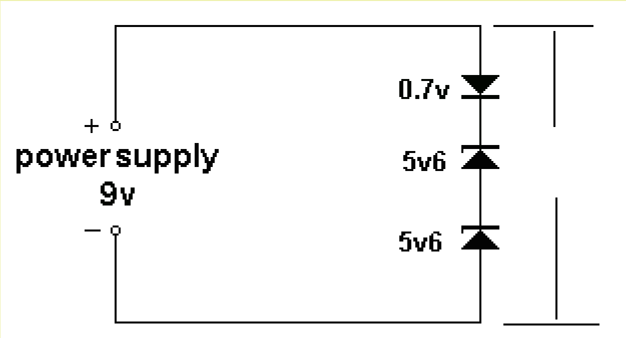
Answer
One diode is around the wrong way. The circuit will not produce a zener reference voltage. The output voltage will be 9v and the string of diodes will have not effect on determining the output voltage.

Question
In the following diagram, If the safety resistor is removed and the 9v supply is connected directly to the two diodes and zener, explain what will happen:



Answer
A very high current will flow through the diodes and zener because the combined zener of the three items is 7v. They will be damaged.

Question
In the following diagram, explain what will happen:

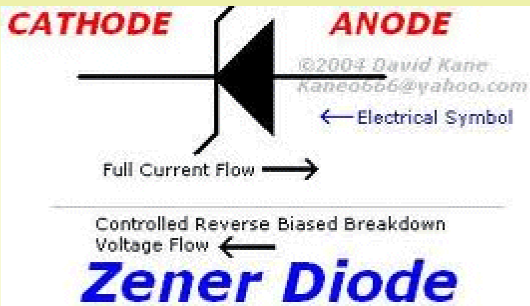


Answer

The zener value of the three components is 11.9v This voltage is higher than the supply (9v) and NO CURRENT will flow in the circuit.

Question

Here's the most absurd explanation of "Voltage Flow" in a zener diode. Can you see the mistake?

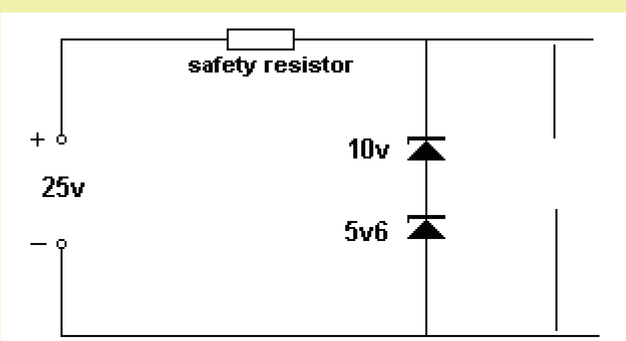


Answer

Voltage does not "flow." Voltage is a potential. It "exists" at each point in a circuit. When the voltage on the cathode is higher than the anode, the zener diode will break-down and current will flow from the cathode to anode. When this happens the zener diode is given a number to represent its voltage (break-down voltage).
When the voltage on the anode is higher than the cathode, current flows and the diode acts just like an ordinary diode (none of the zener properties are used) and the only property you need to remember is the current capability of the diode.

Question

Zener diodes can be connected in series to produce any voltage. Simply add the zener voltages to provide the resulting output voltage. What is the output voltage of this combination:

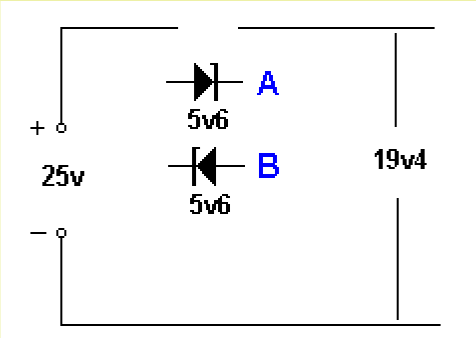


Answer

15v6

Question

Insert zener diode **A** or **B** to produce an output voltage of 19.4v

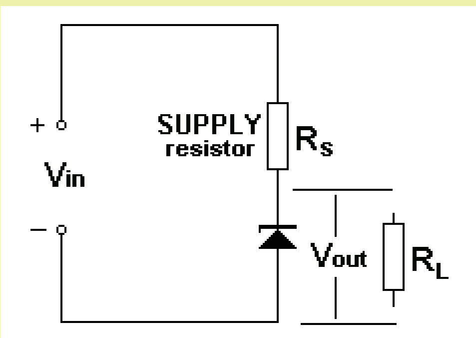


Answer

Zener diode **B**

Question from a reader:

What is the maximum supply voltage for a zener diode?



Answer

Here is the way to work out the Max voltage for Vin:

1. You MUST include a resistor as shown in the diagram above. The resistance of this resistor will be worked out from the following:
2. Select a zener diode for the required output voltage. In other words the ZENER VOLTAGE.
3. Select a 400mW diode, 1watt diode or higher wattage, depending on the current you will be needing.
4. Work out the maximum current though the zener diode:

zener voltage:	400mW	1 watt	10 watt
3v3	120mA	300mA	3 amp
5v1	75mA	200mA	2 amp
10v	40mA	100mA	1 amp
12v	30mA	80mA	800mA
15v	25mA	65mA	650mA
24v	15mA	40mA	400mA

MAXIMUM CURRENT THROUGH ZENER

5. The circuit being designed is called a ZENER REGULATOR or ZENER SUPPLY and the current selected from the table above will flow AT ALL TIMES through the resistor R_s (called the Supply Resistor or safety resistor).
This current is fed into two "loads" - the zener and your load - called R_L
When your load is not taking any current - such as when it is "off" or removed from the circuit, ALL the current will flow through the zener. When you are taking the maximum current, the zener will be taking NO CURRENT. In other words, the two items CURRENT SHARE. They share the maximum current and the sharing can be 0% -100% or 100% - 0%. or any percentage in between.
6. We can now work out the maximum Vin.
7. Vin should be at least 2v higher than the zener voltage. ANY voltage higher than the zener.
8. This voltage is called the HEAD VOLTAGE and any voltage higher than 2v more than the zener voltage is called WASTED VOLTAGE because it will just produce heat in the LOAD resistor and not improve the performance of the circuit.
9. The answer to the question: **What is the maximum supply voltage for a zener diode?** is **ANY VOLTAGE !**
10. We now have to work out the value of the LOAD resistor for 400mW, 1 watt and 10 watt zener diodes when the input voltage is 5v, 10v, 12v, 15v, 24v.
Here are the tables:

Resistor R_L:

Vin = 5v	400mW zener	1 watt zener	10 watt zener
3v3 zener	15R 0.25watt	5R6 0.5watt	

Vin = 10v	400mW zener	1 watt zener	10 watt zener
3v3 zener	56R 0.8watt	22R 2watt	2R2 20watt
5v1 zener	68R 0.4watt	22R 1watt	2R2 10watt

Vin = 12v	400mW zener	1 watt zener	10 watt zener
3v3 zener	72R 1watt	29R 2.6watt	2.9R 26watt
5v1 zener	92R 0.5watt	34R 1.38watt	3.4R 14watt
10v zener	50R 0.1W	20R 0.2watt	2R 2watt

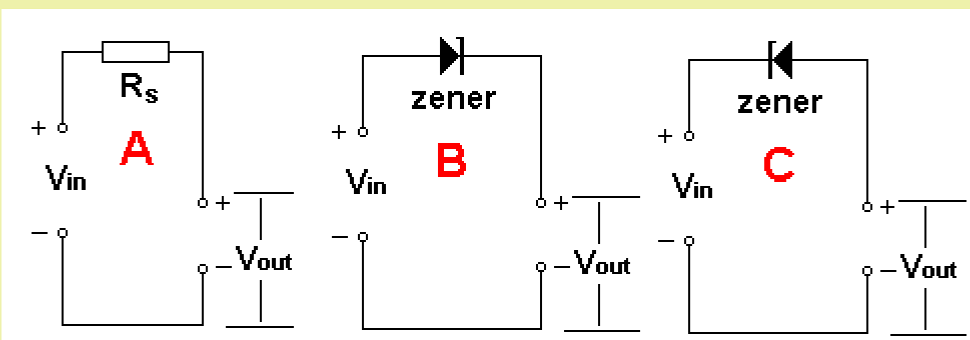
Vin = 15v	400mW zener	1 watt zener	10 watt zener
3v3 zener	100R 1.4watt	39R 3.5watt	3.9R 35watt
5v1 zener	132R 0.4watt	49R 2watt	4R9 20watt
10v zener	125R 0.2watt	50R 0.5watt	5R 5watt
12v zener	100R 0.1watt	37R 0.25watt	3R7 2.5watt

Vin = 24v	400mW zener	1 watt zener	10 watt zener
3v3 zener	172R 2.5watt	69R 6.2watt	too much waste
5v1 zener	252R 1.4watt	94R 3.8watt	too much waste
10v zener	350R 0.56watt	140R 1.4watt	14R 14watt
12v zener	400R 0.36watt	150R 1watt	15R 10watt
15v zener	225R 0.25watt	138R 0.6watt	13R 6watt

The wattage of the resistor is WASTED POWER and some of the designs represent a lot of wasted power.
That's why a zener regulator can be a very wasteful design.
This is called a SHUNT REGULATOR

Question from a reader:

A reader wants to convert 12v to 5v using a resistor or a zener.
Which circuit is best?

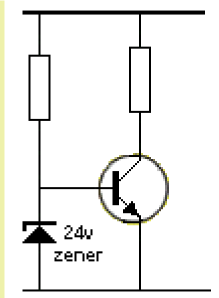


Answer

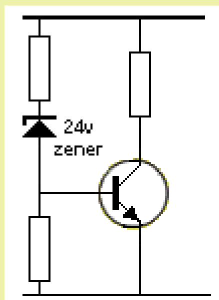
Circuit **C**
Circuit A will produce 5v when say 500mA flows. But if 300mA flows, the voltage will be higher than 5v. If 700mA flows the output voltage will be lower than 5v.
Circuit B has the zener around the wrong way. It will only drop about 0.7v.
Circuit C will deliver 5v if the correct value zener is used and it has the correct wattage-rating.

From from a reader

Here is a mistake from an electronics forum:

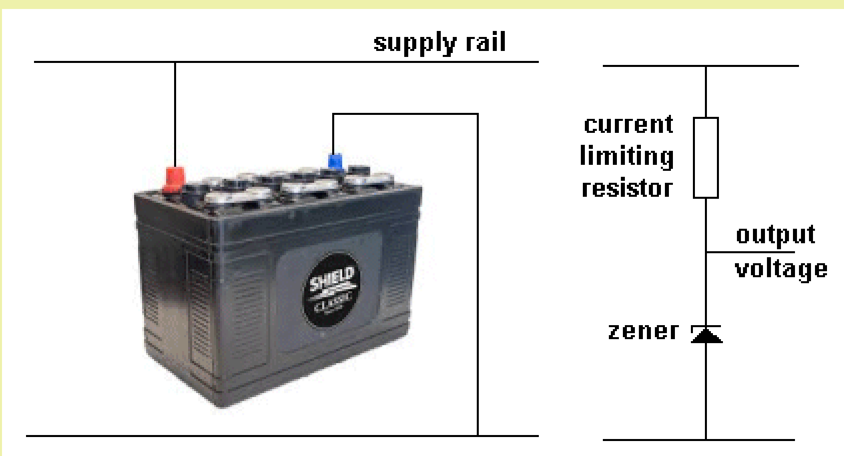


The zener diode is supposed to turn the transistor off when the supply is greater than 24v.
I don't know if the transistor is supposed to be turned ON or OFF, but the circuit will not work.
After reading this article, you will know that a zener is "invisible" until the voltage reaches the zener-value, but the voltage across the base-emitter of a transistor will NEVER rise above 0.7v.
The zener will never see 24v.
The following circuit will work:



When the supply is slightly higher then 24v, the transistor will turn ON.

THE ZENER ANALOGY



A battery and a zener diode behave in a very similar way and if you understand this, you will see why it is very difficult to charge a battery from a power supply. And you understand how a zener diode "eats-up" all the current when the voltage rises over a certain value.

The battery is being charged from the supply rail. We know it will not get charged when the supply rail is less than the voltage of the battery.
As the voltage of the supply rail increases, the battery will take more current but its voltage will not rise above 13.6v.

That's the way the zener works.
It will not allow any current to flow though it until the supply rail is equal to the value printed on the diode. This is its breakdown voltage.
If you increase the voltage of the supply rail, the voltage on the top of the zener diode will not increase, but the extra current that will flow through the **current limiting resistor**, will flow through the diode.

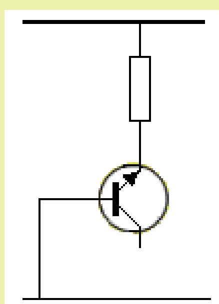
Knowing this helps you charge a battery.
If you connect the battery to a power supply and increase the voltage, a point will come when the voltage is equal to the maximum of the battery (13.6v) and if you continue to increase the voltage, a VERY HIGH CURRENT WILL FLOW and maybe damage your power supply.
The technical answer to this is: There is no current limiting resistor.

THE LED - How it is like a zener diode !

Now we are going to talk about something AMAZING.
It's a LED - LIGHT EMITTING DIODE. It is just like the diodes we have described above and just like the ZENER DIODES we have talked about above.
Yes, that's right a LED is just like a diode and functions just like a diode but it just like a diode with a window so you can see the current flowing through it.
This is a wonderful advantage. Now you can see when a diode or zener diode is WORKING !
But a LED has two slight differences. It is not like a 400v diode but just a 5v diode. A LED can only withstand about 5v to 7v in the reverse direction before it is damaged. This means you can use a LED on any circuit up to about 5v.
And the other thing is a LED can only pass about 20mA, whereas a 1N4004 diode will pass about 1,000mA.
And a LED is just like a zener, but instead of a zener voltage of say 12v, a LED had a zener voltage of 1.7v for red and about 3.6v for white.
Now you can use all your knowledge about diodes and zeners and reference it to a LED in a circuit where less than 20mA is flowing , the voltage is less than 5v and the zener reference is 1.7v to 3.6v or any multiple or addition of these voltages.
This concept is NEW. It has never been explained or covered in any text book in the way we are explaining it.
No-one has thought to show the similarities and that's why you get so many questions on electronics forums about the operation of a LED and why you need a current-limiting resistor.

THE TRANSISTOR AS A ZENER DIODE

A transistor exhibits "ZENER CHARACTERISTICS" when placed in a circuit as shown in the following diagram:



The base-emitter junction is "reverse biased." In other words, it has voltage across it that is opposite to the normal way the transistor is used.
The junction cannot withstand a very high voltage in this direction and it BREAKS-DOWN.
In other words it starts to allow current to flow through the junction and a voltage is created across this junction. The resistor is provided to prevent a high current to flow through the junction and to allow the junction to break down and create the natural value across the two leads.
This is called ZENER BREAKDOWN.
The voltage will depend on the type of transistor and can be anywhere from 6v to 8v. For a particular type of transistor it will be quite stable (fixed) and you can allow say about 10mA to flow through the junction. The transistor will not be damaged.

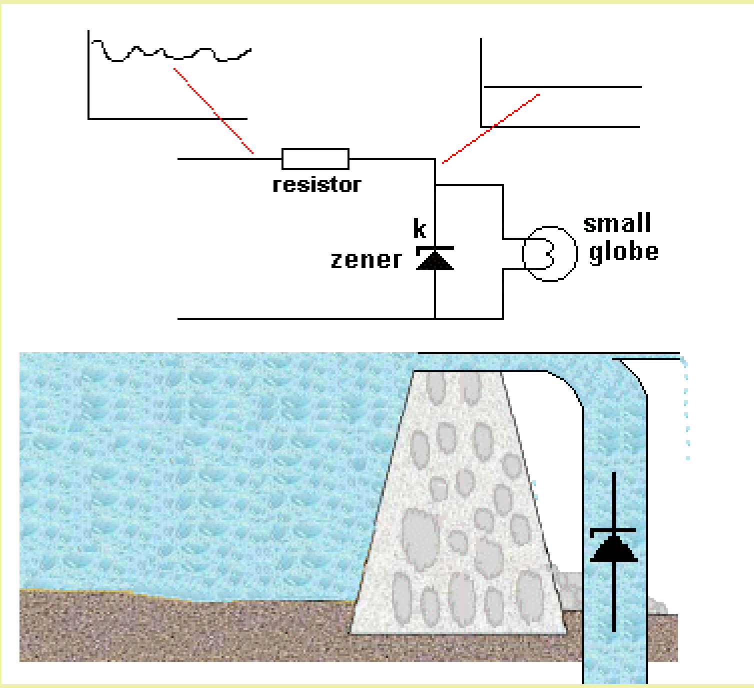
THE SHUNT REGULATOR

We will now combine all the facts we have learnt from above to produce a circuit called a **SHUNT REGULATOR**.
A **Shunt Regulator** takes a high voltage (containing ripple) and produces a lower FIXED voltage with very little ripple.
We have learnt that:
1. A BRIDGE converts AC to DC (pulsating DC. DC with ripple).
2. An electrolytic smoothes the pulsating DC and reduces the ripple.

A shunt regulator FURTHER REDUCES THE RIPPLE and produces A FIXED VOLTAGE.
A SHUNT REGULATOR consists of two components: A **resistor** (called the current limiting resistor) and a **zener diode**.

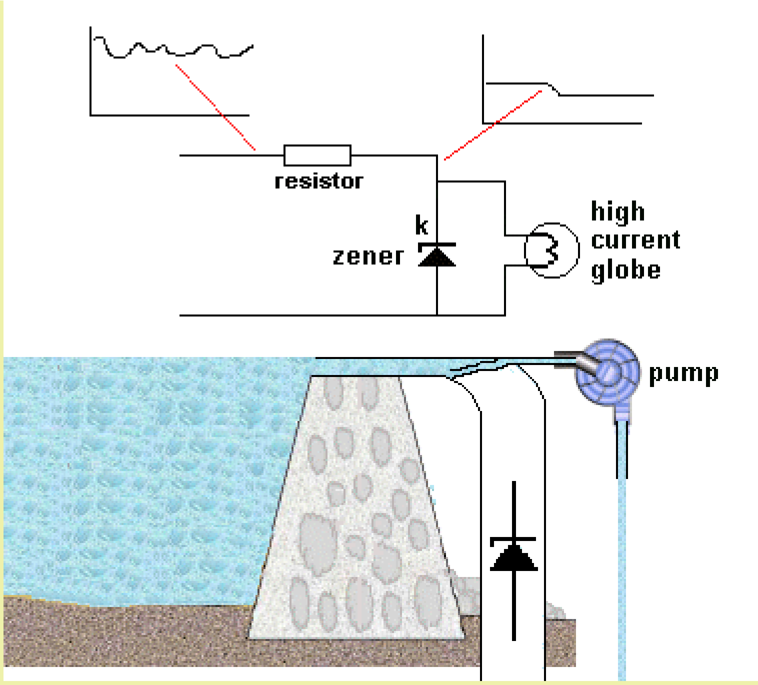
Here's how the **SHUNT REGULATOR** works.

Firstly, the zener diode and resistor work just like a dam with an overflow pipe at the top. If the water level in the dam does not reach the pipe, NO water overflows. When the water reaches the pipe, it overflows through the zener pipe. If the water level rises further, more water flows through the zener.



The height of the water is never above the small overflow pipe.
The small overflow pipe is connected to the globe and the brightness of the globe is constant because the voltage on the cathode of the zener is fixed (by the action of the zener diode).
It does not matter how much ripple is present in the incoming waveform, the value of the resistor is chosen to eliminate ALL THE RIPPLE.

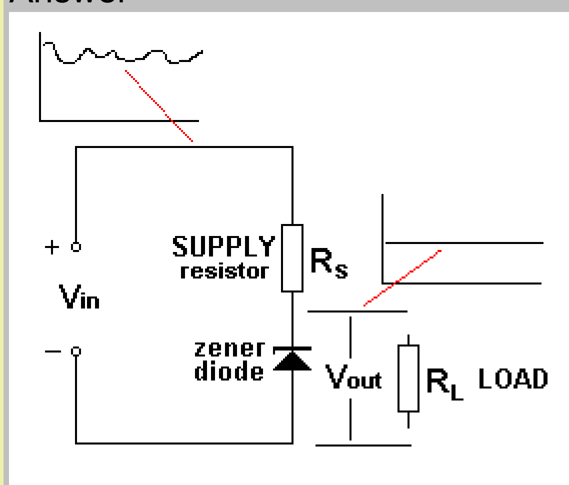
The mathematics to work out the value of the resistor is very complex as it involves the resistance of the resistor, its wattage and the wattage of zener.
This is covered in the article: **The [Power Supply](#) and also above with a set of tables.**
The height of the small overflow pipe can be taken to a LOAD such as GLOBE.
The load can only be a SMALL LOAD. In other words, it can only require a small current, such as a small torch globe.
If the load takes **ALL THE CURRENT** (coming from the resistor), the zener will get NO CURRENT and it will DROP OUT OF REGULATION.
In other words, the voltage on the cathode of the zener will drop.
This is exactly like putting a pump on the small overflow pipe and sucking all the water from the zener:



Question

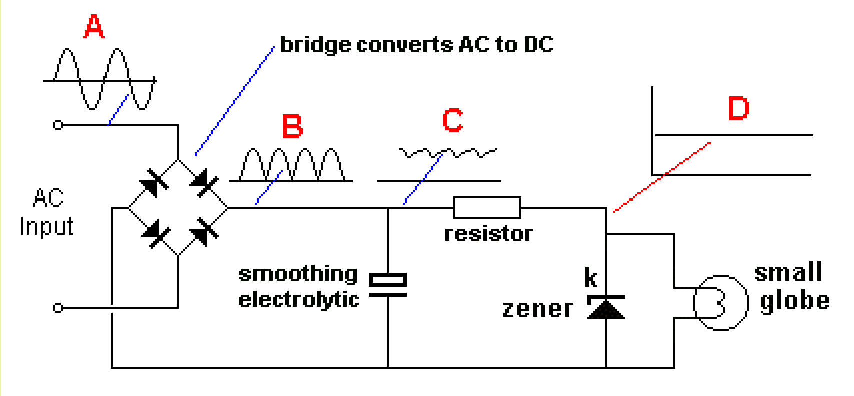
Why use a SHUNT REGULATOR?

Answer



A SHUNT REGULATOR is a very cheap and simple way to produce a clean output voltage (with very little ripple) from a higher voltage that has ripple.

We can now add the bridge and smoothing electrolytic:



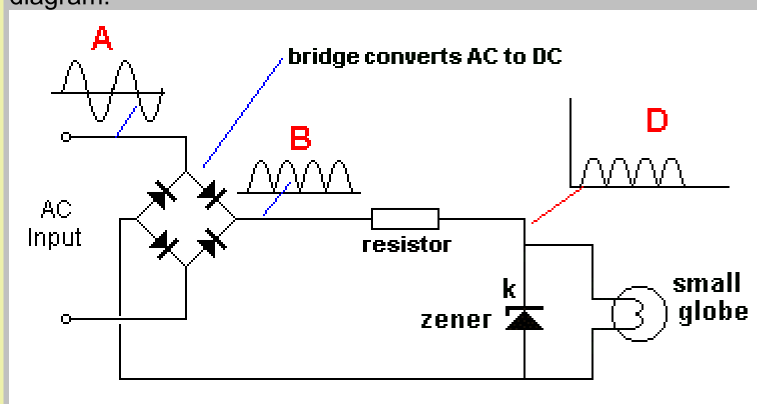
Waveform **A** is an AC voltage and you can see it rises to a peak above the zero-voltage line and equally below the 0v line.
Waveform **B** represents the waveform as it emerges from the bridge. (The electrolytic is not connected to detect this waveform.)
Waveform **C** shows the effect of the electrolytic. It stores energy from the peaks and delivers the energy when the waveform drops. The result is DC with a small amount of ripple.
Waveform **D** is very smooth DC at a voltage determined by the voltage of the zener.

Question

In the diagram above, describe the shape of the output voltage **D** if the electrolytic is removed

Answer

The pulsing DC will produce a waveform on the cathode of the zener as shown in the following diagram:

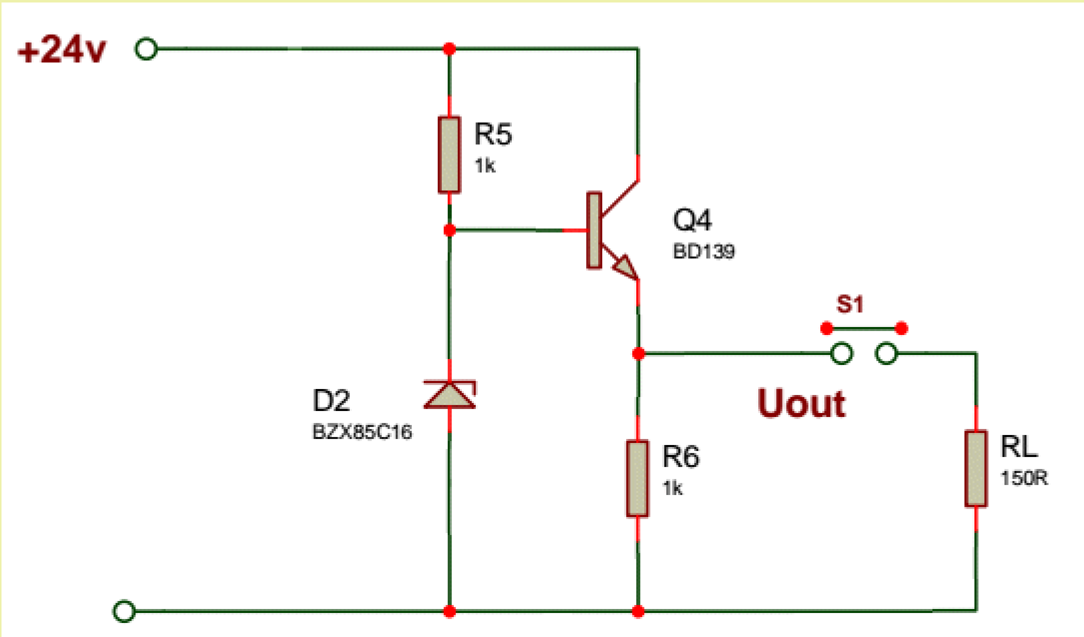


This will not matter if the load is a globe but if the load is an amplifier, the power supply will produce HUM.

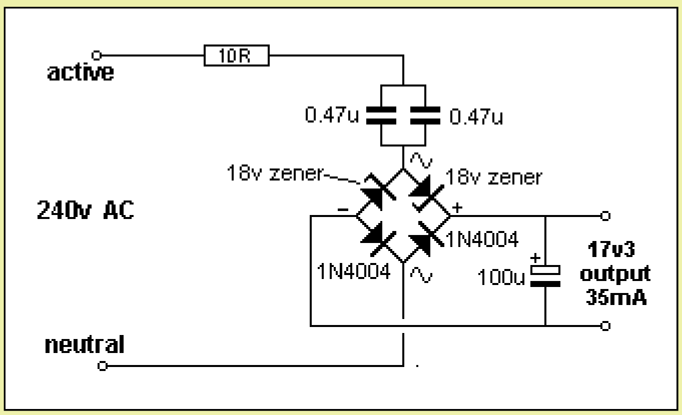
THE SERIES REGULATOR

The SERIES REGULATOR can be identified by the fact that the zener diode does not pass all the current when the load is removed.
This type of circuit is much less wasteful than the Shunt Regulator.
You can also see the current (actually the voltage and the current) passes through the controlling device (the transistor) and then the load, just like two components in SERIES.
In fact, we have a shunt situation with the zener and 1k resistor as the voltage across the 1k is 8v and this causes 8mA to flow through the 1k and thus the zener has 8mA flowing through it.
If the transistor has a gain of 50, it will allow up to 8 x 50 = 400mA to flow through the collector-emitter circuit.
But if you try to take more than 400mA (by connecting a load with a very low resistance) the whole circuit will DROP OUT OF REGULATION.
This means the output voltage will drop below 15.4v.
Let's see how this happens.
When the load takes 50mA, the collector-emitter leads of the transistor deliver this current and the base takes 1mA from the zener diode. This means the zener sees 7mA.

When the load takes 400mA, the base takes 8mA and the zener diode gets NO current.
Up to this point, the circuit works perfectly.
But if you take 450mA, the base requires 9mA and when 9mA flows through the 1k resistor, the voltage across the resistor is 9v.
This means the base is 24v - 9v = 15v and this voltage is lower than the breakdown voltage of the zener.
The zener only has the capability of preventing the voltage **rising above** 16v, it does not have any control when the voltage delivered to it is less than 16v.
The output voltage is now 14.4v and the circuit is said to have DROPPED OUT OF REGULATION.



Here is an unusual use for a zener diode in the bridge of a power supply:



This is a very special type of power supply called a **TRANSFORMERLESS POWER SUPPLY** and it shows the effect of putting a diode in the bridge that has a very low breakdown voltage. Normally the 4 diodes will have a peak reverse voltage (breakdown voltage) of 200v or 400v and this effect will not be noticed. But when two 18v zeners are included to demonstrate the effect of "breakdown voltage" the output of the supply is 18v minus 0.7v across the lower diode.

CURRENT SHARING

The current though the zener and the current though the small globe is called **CURRENT SHARING**. They share the current coming from the resistor. The resistor is called a **FEED RESISTOR** or **FEEDER RESISTOR** or **CURRENT LIMITING RESISTOR** or **CURRENT DETERMINING RESISTOR**. It is NOT a LOAD RESISTOR.
It is designed to deliver **CURRENT** to the zener and globe. The globe is the LOAD.
A shunt regulator consisting of a zener (and resistor) is designed to deliver a **small** current. If a large current is required, a transistor is added to the circuit, called a PASS TRANSISTOR or a number of different circuits can be used.

We will now cover **CURRENT SHARING**:

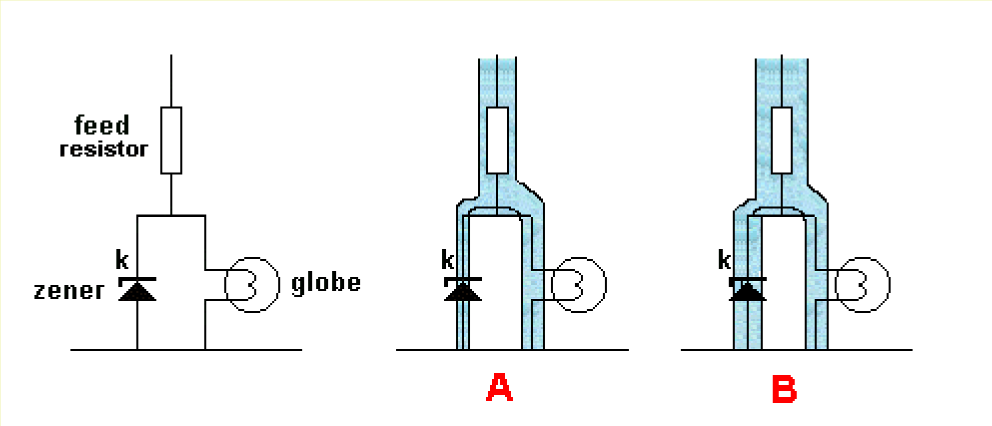
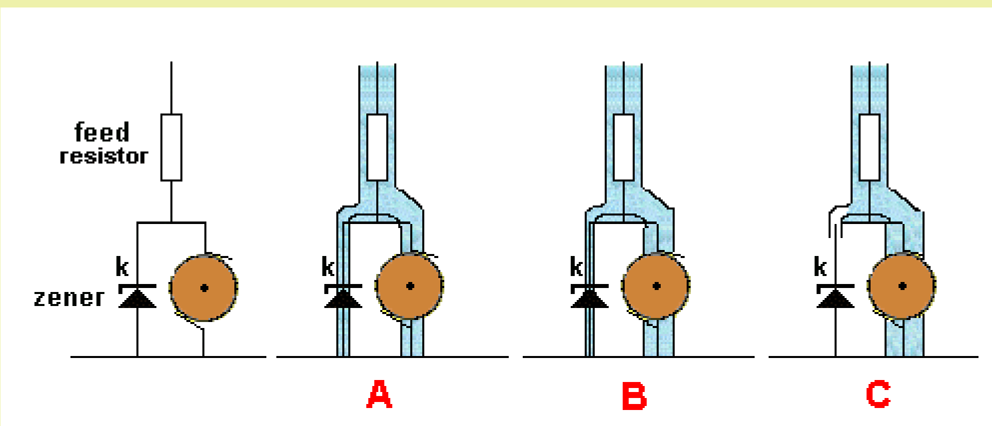


Diagram **A** above shows the correct **CURRENT SHARING** between the zener and globe. The zener should only be taking a few milliamps as this current is wasted and the zener is only required to provide a fixed voltage.
However if the load is removed, all the current taken by the load will not flow through the zener and that's why the zener must be capable of dissipating this wattage.
Diagram **B** shows what will happen if the supply voltage increases. The CURRENT through the feed resistor will increase. This is similar to more water flowing though the pipe containing the feed resistor and the extra water will flow though the zener.
Here is the reason:
The voltage on the cathode of the zener is **fixed** (the voltage delivered to the globe is fixed). This means the current taken by the globe will remain constant. Thus any extra current can only flow though the zener.

We will now change the globe for a motor:

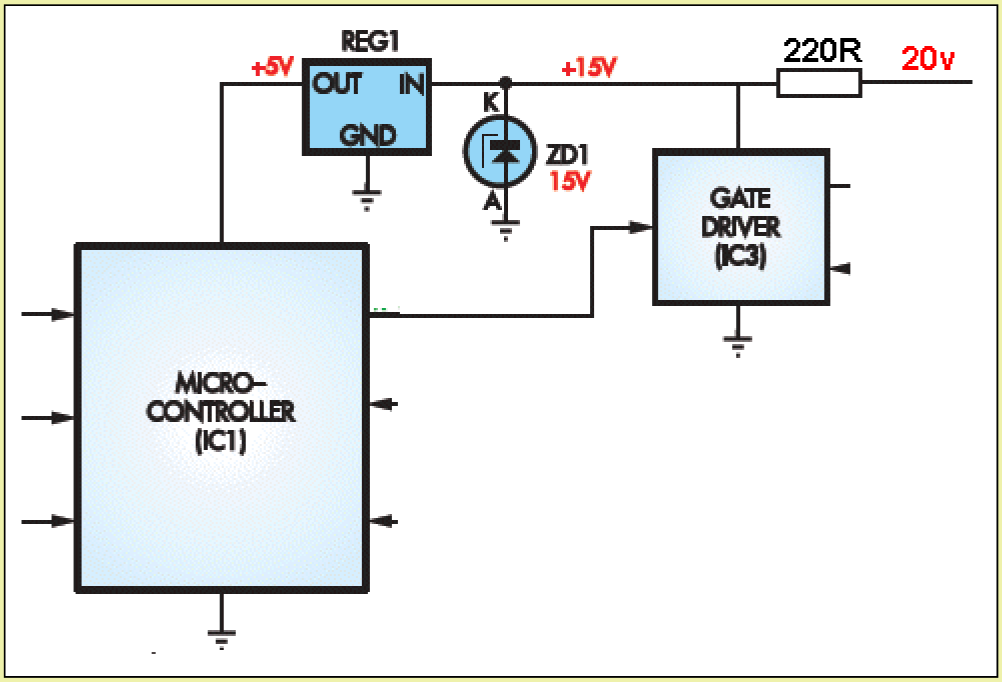


If the supply voltage remains constant and the motor takes more current, it robs the current from the zener. This shown in diagram **B** above. If the motor takes even more current, it will take **ALL THE CURRENT** from the zener. This shown in diagram **C** above.
Up to now the voltage across the motor is constant. But if the motor wants more current, the **SHUNT REGULATOR** will **drop out of regulation** and the voltage across the motor will DROP. The motor may or **may not** get more energy from the supply, but we will not go into this condition because the SHUNT REGULATOR has ceased to perform.

The **SHUNT REGULATOR** is called a SHUNT REGULATOR because the zener is connected directly across the voltage being delivered to the LOAD and it "shunts" (takes away) ALL the current being delivered by the resistor (if the load is removed). When a LOAD is connected, it takes current from the zener and it can do this until almost all the current is taken.
You must leave a small current through the zener to keep the circuit in REGULATION.
The **SHUNT REGULATOR** is a very wasteful design as current is flowing ALL THE TIME. If the load is not using the current, it is being wasted through the zener.

CURRENT SHARING can also be also be applied to placing two equal diodes in parallel. This can be ordinary diodes or zener diodes.
Take the case of "power diodes."
Suppose you have a 1-amp power supply and intend to use four 1N4004 diodes in a bridge. We have already mentioned that this type of diode has a voltage drop of 0.7v when the current is about 500mA but increases to 1.1v when the current is 1 amp.
By using an extra set of four diodes in parallel with the first set, the current through each diode will be shared. The current may not be shared equally, but it will be much less than 1amp (through each diode) and the overall wattage-loss will be less and this will be shared between two diodes. Overall, a very good outcome.

ACTUAL ZENER CIRCUIT



Here is a circuit using a 15v zener diode.
Here's how to look at this circuit:
The input voltage is 20v.
Remove the three "rectangles."
The zener diode will create a rail voltage of 15v and all the current from the 20v supply will pass through the zener.
This current can be worked out by looking at the 220R resistor. It has 5v across it and the current flowing will be: V = I x R 5 = I x 220 = 5/220 = 22mA
The regulator requires a small current to drive the transistors inside the chip. Say this is 2mA.
The Microcontroller requires a small current to operate. Say this is 6mA.
The gate driver uses 1mA.
The remaining 13mA flows through the zener.
Suppose the microcontroller turns ON and output line and takes an extra 13mA.
This means NO CURRENT will flow through the zener and it will DROP OUT OF REGULATION.
The rail voltage will remain at 15v but the zener will have no part in this circuit (at the moment).
If the micro wants say 2 more milliamp (to drive another output device) the 15v rail will drop slightly.
The 5v rail will remain at exactly 5v and the 15v rail will drop a small amount.
This circuit is called **CURRENT SHARING**.
The 3 devices in the rectangles SHARE the current with the zener. There is 22mA to share between the 4 items.
You can also say the 3 devices TAKE current from the zener or ROB (steal) current from the zener and when all the 22mA is STOLEN, the 15v rail drops in voltage and we have lost what is called **ZENER REGULATION**.

GATING - how a diode can be used as a GATE

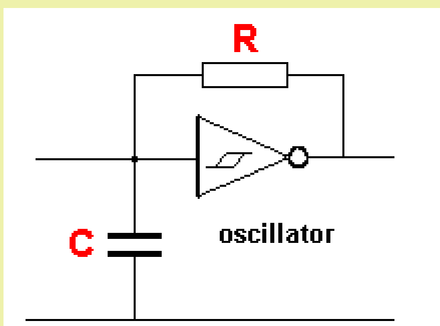
The technical way to describe a diode is:
A diode only allows current to pass in one direction.
This also means a diode only allows voltage to appear on the cathode when the voltage on the anode is above 0.7v.

We can use this feature to INHIBIT (stop) an oscillator and also produce circuits where two or more inputs determine the output of a circuit.
This is called **GATING.**
We will cover two features, **Gating An Oscillator** and creating **Diode Gates**

GATING AN OSCILLATOR

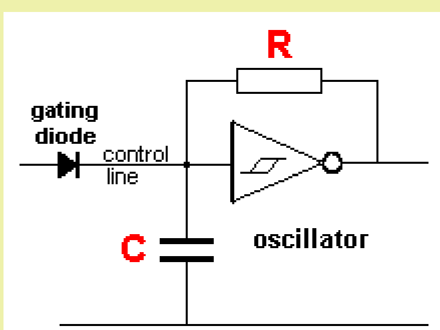
We are not interested in how the oscillator works. We want to STOP or INHIBIT the oscillator via an input signal.
The simplest type of circuit to "control" or "gate" is a DIGITAL OSCILLATOR. This is an oscillator made up of a BUILDING BLOCK contained in an INTEGRATED CIRCUIT.
The Building Block is also called a GATE and we have two terms called "GATE" in this discussion.
The Building Block may be an **AND** gate, **OR** gate, **Inverter** or **Schmitt Trigger**.
The other "gate" in this discussion is the action of turning ON or turning-OFF the oscillator.
The "gate" is the diode on the **CONTROL LINE** and it is taken HIGH or LOW to control the oscillator.

In the following circuit, the INTEGRATED CIRCUIT (IC) contains 6 Schmitt Triggers and each Schmitt Trigger is called a **BUILDING BLOCK** or **Schmitt Gate**. It oscillates due to the resistor **R** and capacitor **C**.

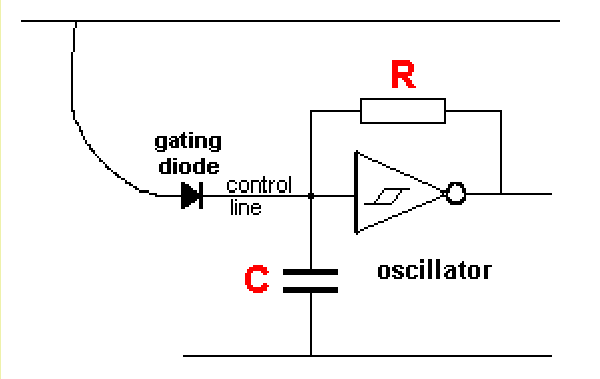


The voltage on the capacitor "C" rises to 2/3 rail voltage (via resistor "R") and this is detected by the IC to make the output LOW. The capacitor now discharges to 1/3 rail voltage via resistor R and the IC detects a LOW to make the output HIGH. An animation of the circuit is available from Talking Electronics on the CD of the whole site. [Subscribe to the CD for $10.00.]

A gating diode can be placed on the "control line" to control (inhibit) the oscillator:

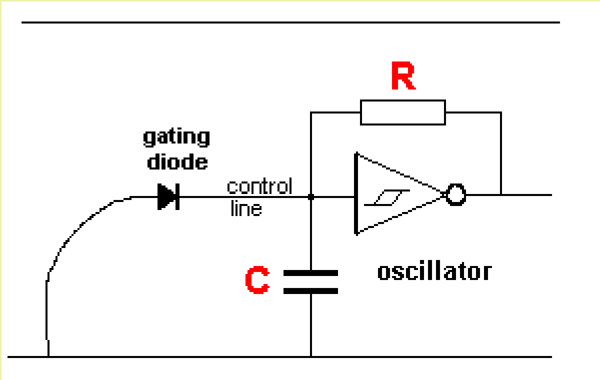


When the gating diode is taken HIGH, the oscillator is "jammed" (inhibited - frozen):



The oscillator is INHIBITED

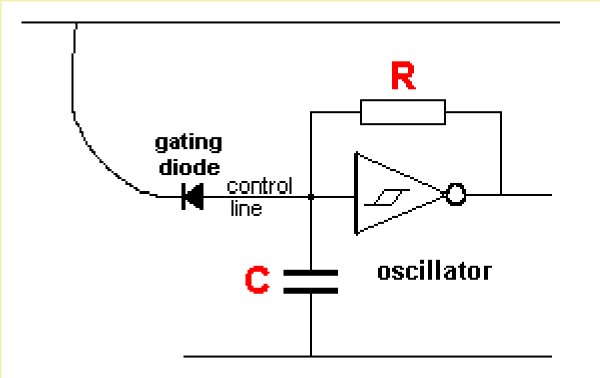
In the diagram above, the voltage through the gating diode will keep the capacitor charged and prevent the IC changing state. The oscillator is INHIBITED.



The oscillator is NOT inhibited

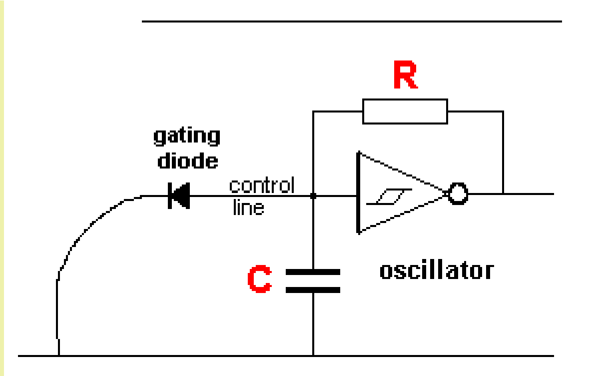
In the diagram above, the gating diode does NOT inhibit the oscillator. The oscillator produces a square-wave output.

If the gating diode is reversed, a HIGH on the cathode will NOT inhibit the oscillator:



The oscillator is NOT inhibited

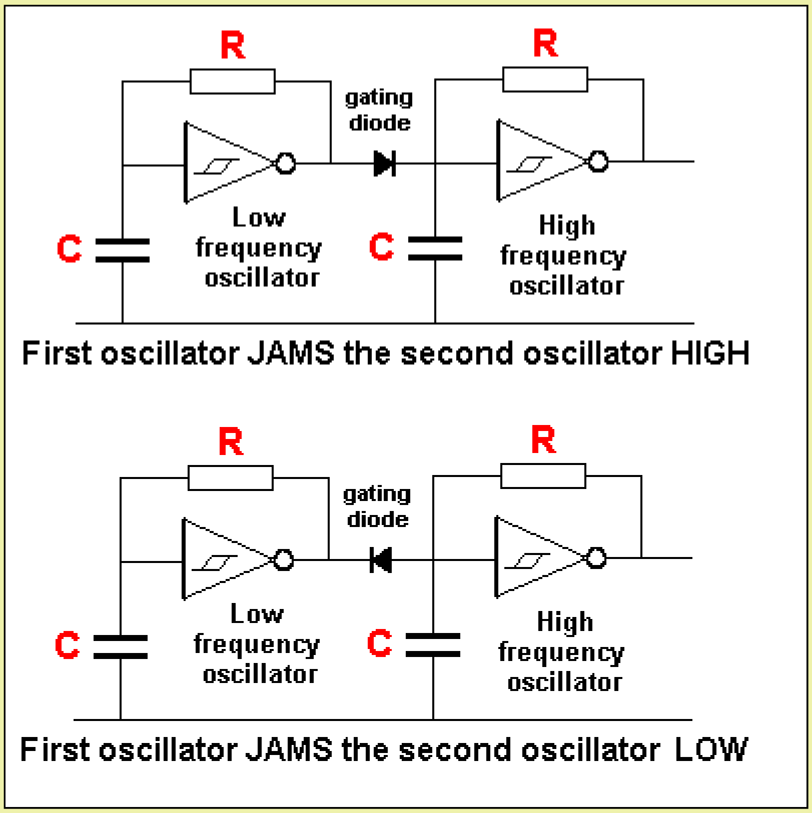
A gating diode connected to 0v, as shown below, will inhibit the oscillator:



The oscillator is INHIBITED

The gating diode will only allow a voltage of 0.7v to appear across its leads. This voltage is too low for the input of the IC and thus the circuit will not change state. The oscillator is INHIBITED.

The gating diode is normally connected to the output of a controlling circuit, as shown below:



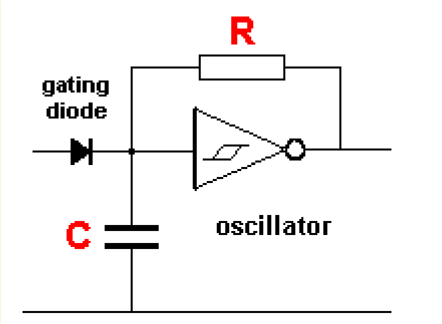
The first oscillator controls the second oscillator via the gating diode.
The operation of the Schmitt Trigger oscillators is fully covered in the Interactive section of Talking Electronics website and on the CD of the whole site. Subscribe to the CD for $10.00.
We are only covering the operation of a diode in this discussion.

THE GATING DIODE

It is important to understand the effect of a gating diode on the operation of an oscillator (as shown in the diagrams above).

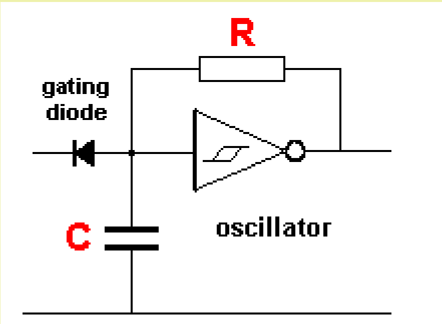
Question

Is the oscillator inhibited (stopped - halted - frozen) when the anode of the gating diode is HIGH?



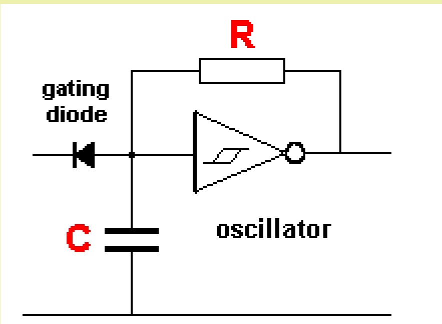
Answer
Yes. The voltage via the diode will keep the capacitor charged and the oscillator will be frozen with the output low.

Question
Is the oscillator inhibited when the cathode of the gating diode is HIGH?



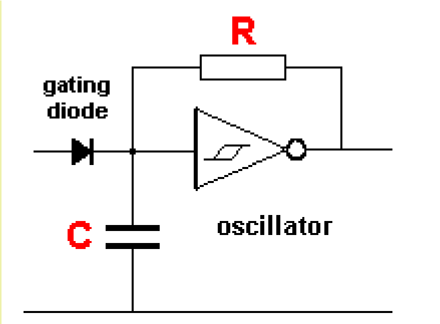
Answer
No. The voltage on the cathode will not pass through the diode and the operation of the oscillator will not be affected.

Question
Is the oscillator inhibited when the cathode of the gating diode is LOW?



Answer
Yes. The 0v on the cathode will put a maximum of 0.6v on the anode and this will keep the capacitor discharged and the oscillator will be frozen with the output high.

Question
Is the oscillator inhibited when the anode of the gating diode is LOW?



Answer
No. 0v on the anode will not pass through the diode. The diode will allow a voltage of at least 100v to appear on the cathode and thus the operation of the oscillator will not be affected.

DIODE GATES

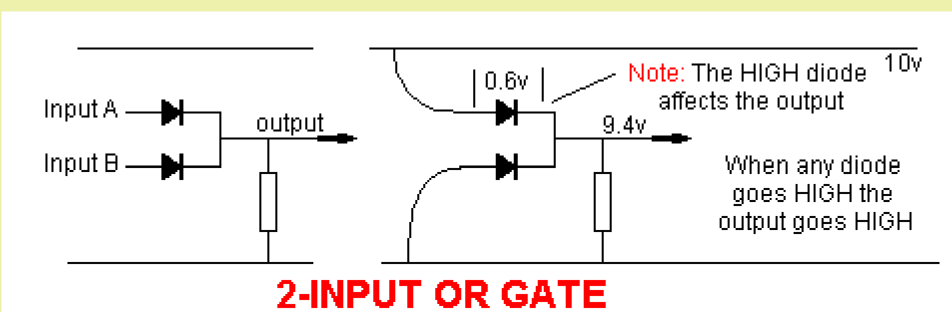
Diodes can be connected so that two or more CONTROL LINES determine the state of an output.
This is called GATING and more-specifically **DIODE GATING**.
The two diode gates are: **AND GATE** **OR GATE**.

An **AND GATE** is **HIGH** when both inputs are **HIGH**.
An **OR GATE** is **HIGH** when either input is **HIGH**.

Notes:
1. For a Diode Gate, we are not concerned with the 0.6v to 0.7v drop across the diode.
2. A Diode Gate is classified as DIGITAL GATE. In other words, the output is either HIGH or LOW.
3. When it is HIGH, the output is as close to the rail voltage of the system as possible. This voltage is normally 5v, but it can be 3v3 for a 3v3 system or 12v of other systems.
4. When it is LOW, the output is as close to 0v as possible.

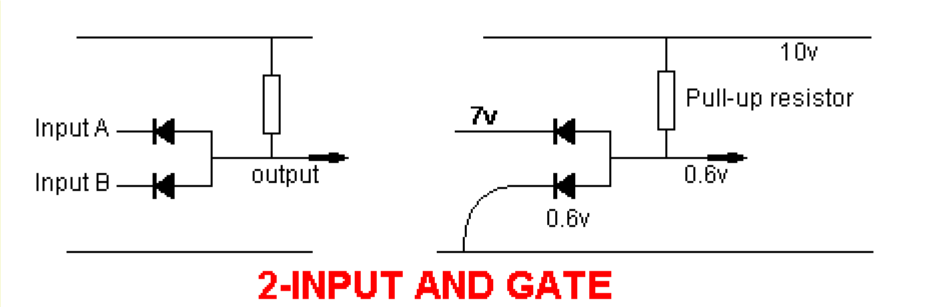
THE DIODE OR GATE

The voltage and current is passed to the output by the incoming signal and a pull-up resistor is not needed. A pull-down resistor will prevent the output "floating."
The output will go HIGH when line A **OR** line B is HIGH (and also when BOTH inputs are HIGH).
A voltage-drop of 0.6v is lost across the diode but this will not affect any circuit using this gate.



THE DIODE AND GATE

For the diode **AND** gate, BOTH input A **AND** input B must be HIGH for the output to be HIGH.
The diode AND gate works in a slightly different way to the diode OR gate.
The pull-up resistor delivers the output voltage and current.
The input lines ALLOW the output voltage to rise when BOTH inputs are HIGH. The output current of the AND gate is determined by the value of resistor R. When the output is low, this current is termed BLEED CURRENT and flows through the diode(s) to the 0v rail. This current is "waste" current and must be kept to a minimum for good design.

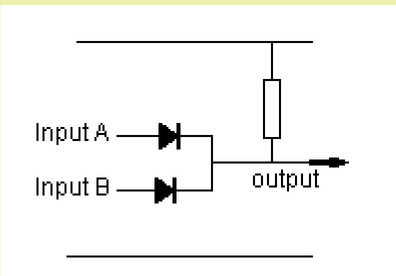


Note:

NAND and NOR gates cannot be produced with diodes and resistors as these gates involve INVERSION and a diode cannot provide inversion. A transistor or IC is needed to provide inversion.
The **OR** and **AND** gates above are called DIGITAL GATES because the output is HIGH or LOW. This condition is created because the input lines are DIGITAL LINES - they are either HIGH or LOW.

Question

Is the following circuit an **AND** gate or **OR** gate:

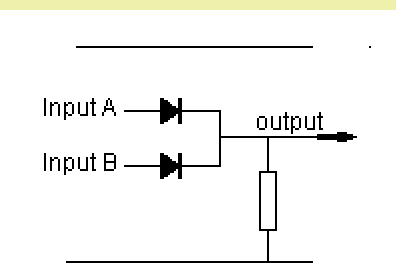


Answer

The two diodes are connected around the wrong way. The circuit is not and **AND** gate or **OR** gate.

Question

Is the following circuit an **AND** gate or **OR** gate:

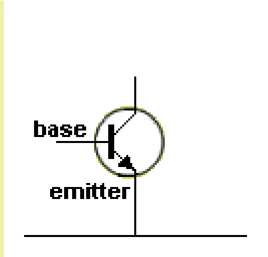


Answer

The gate is an **OR** gate.

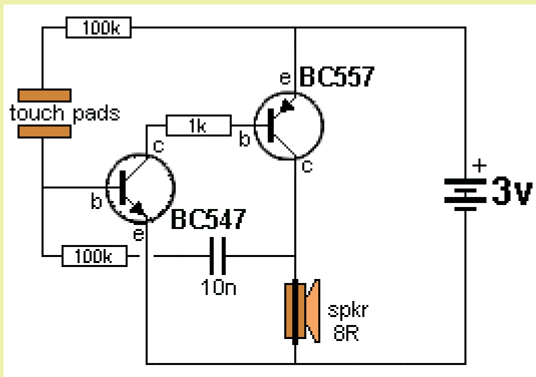
THE TRANSISTOR

A transistor can be considered to have a diode between between the base and emitter leads because these two leads behave just like a diode. We have shown an NPN transistor in the diagram below, but the same applies to a PNP transistor.



An NPN Transistor

This fact is important to know when analysing circuits such as this one:



Lie Detector

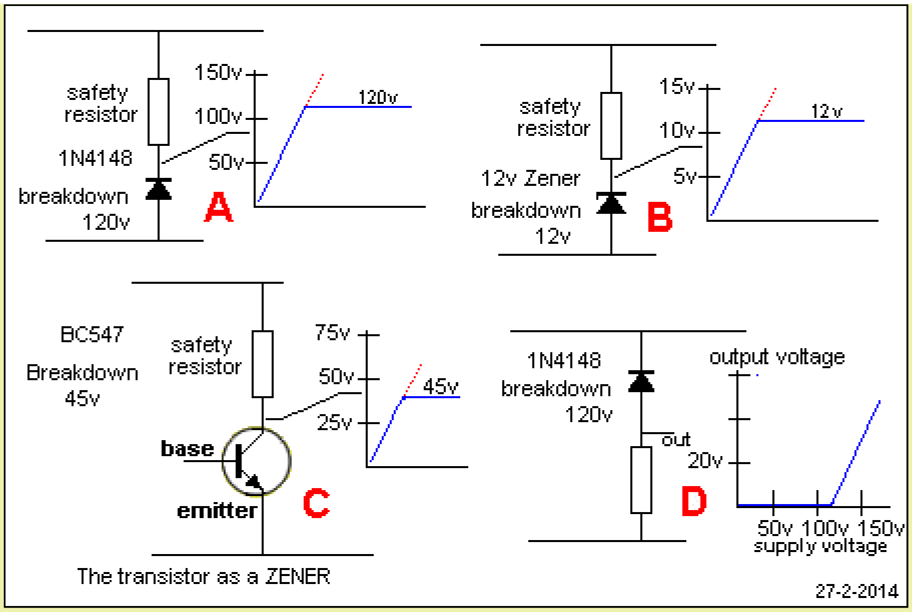
The circuit will not start to turn ON until the voltage on the base of the NPN transistor is 0.6v. This voltage is provided by your finger on the Touch Pads and the top 100k resistor.

At the beginning of this article we mentioned the fact that the voltage across a diode can be increased from 0v to 0.55v and nothing flows through the diode.
This is exactly the same effect with the base of a transistor.
The transistor does not conduct until the voltage on the base reaches 0.6v and if the voltage is increased, above 0.55v, current will start to flow "through the diode" - "through the base lead to the emitter."
Although a diode and base-emitter junction of a transistor are NOT the same thing - we can use this simple explanation to understand how the two components work.

In the case of a diode, as the voltage is increased over 0.6v, more current flows through the diode. In the case of the base of a transistor, as the voltage is increased over 0.6v, the transistor turns ON more and more current flows through the collector-emitter terminals.
(The voltage 0.6v can range from 0.6v to 0.9v, depending on the type of diode and the current flowing.)
The whole point to understand is this: NO current flows until the voltage across the diode is 0.55v and as the voltage is increased, more current will flow (in the case of a transistor).
In the case of a diode, you can add this interpretation: As the circuit requires more current, the additional current will flow though the diode and create a higher voltage-drop across it.

BREAKDOWN

When a diode, zener diode and/or transistor sees a HIGH VOLTAGE across **ANY** of the leads, it will BREAKDOWN.
No semiconductor device can withstand a very high voltage and we will look at what happens.
This is a very important topic because we use this breakdown feature in some circuits and other times we need to know how to prevent breakdown.
If a transistors sees a high voltage such as a spike (and the voltage has a reasonable amount of current) the transistor will be instantly damaged.
If the current is low, the transistor can be repeatedly operated with the feature.
Here's what will happen to a diode, zener diode and transistor:



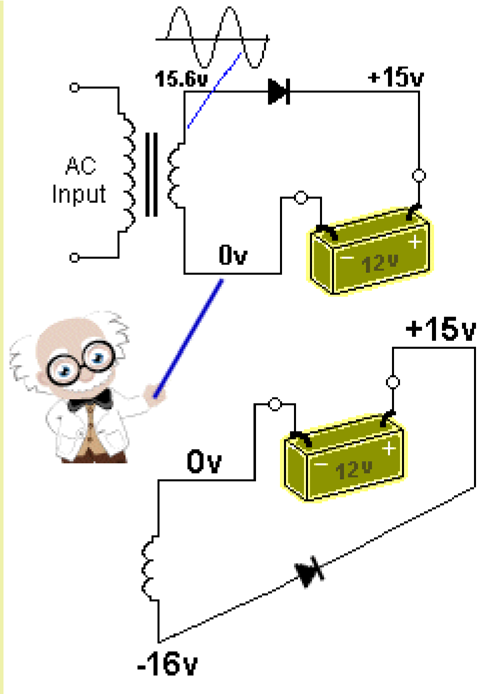
The voltage across a signal diode or power diode or zener diode will be equal to rail voltage when the voltage is below the breakdown or Avalanche voltage of the diode. In other words, no current will flow through the safety resistor and no voltage will be dropped across this resistor. However, when the voltage reaches the Peak Inverse Voltage for a Diode, or the avalanche voltage for a zener, the device will breakdown and cause current to flow through the device so that the voltage on the cathode will not rise any further. As you increase the voltage, the current through the device will increase but the voltage across it will not change. The device will get hotter and hotter until it fails with overheating.

The same will occur with a transistor. When the voltage on the collector reaches the maximum for the transistor, it will breakdown and the voltage across the collector-emitter will remain at this voltage.

Fig **D** shows how a diode (or zener diode) can be used to pass voltages that are higher than the breakdown voltage of the device. Nothing flows though the device until the breakdown voltage is reached and then the exact-same-waveform flows though the device.

Note: When the three devices are connected in the reverse direction the diode and zener will drop (breakdown) at 0.6v and the transistor will breakdown at a very low voltage.

WHY DOES A DIODE FAIL?



The PIV on the diode is 31v

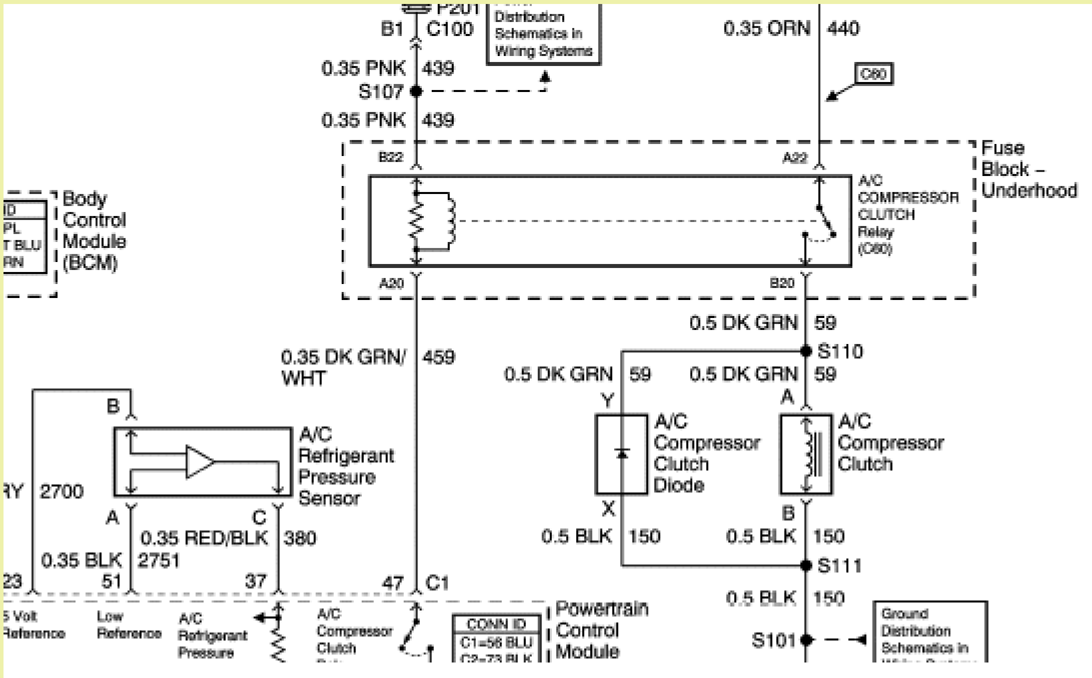
Here we have a simple circuit for charging a battery. The diode is 4 amps with a PIV rating of 30v. The PIV rating is the voltage the diode is capable of withstanding in the opposite direction. This is just an example of what will happen.
When the output of the transformer is positive on the top, the voltage across the diode is about 0.6v (or as high as 1v when 4 amps flows) and the wattage dissipated by the diode is about 4 watts.
When the voltage reverses direction, the top output of the transformer becomes NEGATIVE and it just like the winding "flips-over" to produce the second circuit.
The diode sees a negative voltage on one end and a positive voltage on the other lead.
This means a total of 15 and 16 = 31 volts is across the diode.
When the voltage reaches 30v, this is the PIV voltage for the diode (this can also be called the zener voltage) and it BREAKS DOWN at 30v so that any voltage higher than 30v allows current to flow through the diode FROM THE BATTERY to the TRANSFORMER. This current will be very large because the battery is capable of delivering a high current and the transformer winding will be a thick wire and if it is capable of delivering 4 amps when charging the battery, it will accept a higher current in this "break-down" condition.
The current will be as high as 5 to 10 amps or more.
Suppose 5 amps flows.
The wattage dissipated by the diode will be 5 x 30 = 150 watts. Obviously the diode will be destroyed very quickly.
That's why a diode in a 12v battery-charger needs to have a PIV rating higher than 30v.

HEATSINKING

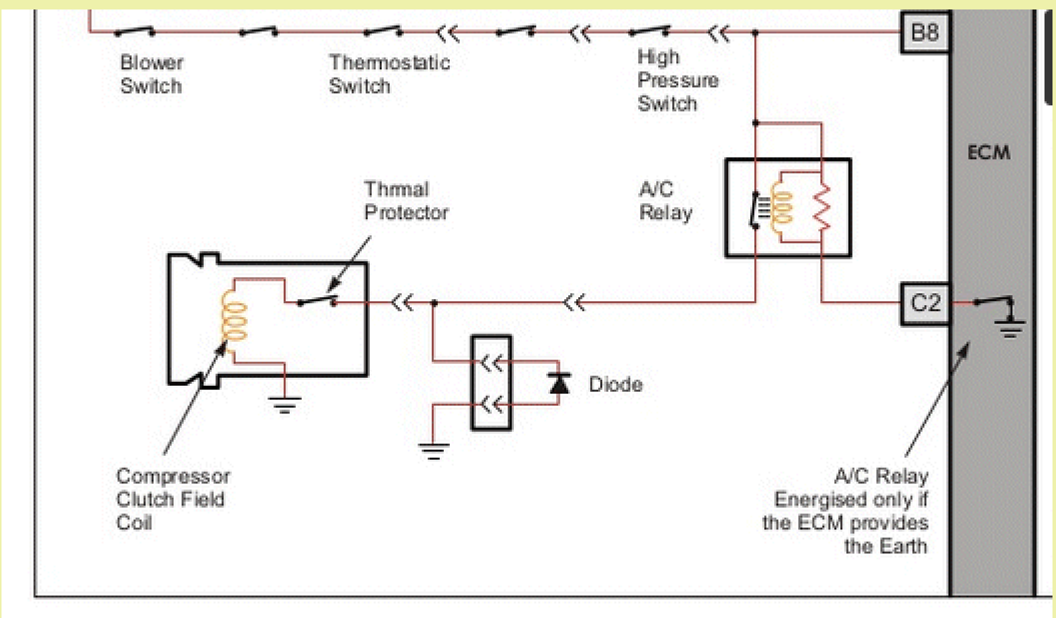
You might not think a power diode needs to be HEATSINKED because there are no heat-fins on a diode. But the leads and pads on the PC board form a very important part of getting rid of the heat generated.
The author has seen examples of one pad being smaller than the other and the lead heated up the solder to produce a dry joint.
In another case, the small pads resulted in the diode overheating and "shorting;" and other diode "going open."
So, the quality of the heatsink is VERY IMPORTANT.
If you cannot hold your finger on a diode for 10 seconds, it is TOO HOT.
Adding extra-wide pads and tracks on the underside of the board is a very good idea.
Power diodes are very robust, however it is good engineering to add extra track-work to prevent over-heating.

PROBLEM FROM A READER:

I am working on a automotive air-conditioner system that keeps blowing fuses.
I disconnected the compressor and the fuse still blows. I figure I have either a short to ground on the wire from the relay to compressor....or maybe there is something going on with the diode.
Here is the circuit:



Circuits with lots of plugs and numbers and figures are very hard to follow.
Here is a simplified circuit to show the diode is connected between the positive line into the compressor clutch and ground:



If the diode is "shorted" it will put a low resistance on the line into the clutch and "blow the fuse." This is the first component to replace, as a short-circuit in the wiring is a rare problem. Remove the diode and check the resistance in both directions with a multimeter set to LOW OHMs. Alternatively, connect the diode to the positive lead of a 12v globe and then a 12v battery. Now turn the diode around the other way. The globe should NOT illuminate.
A diode can fail due to vibration, heat, stress on the leads, or voltage spikes. Although these faults are rare, you must remember these are all possibilities as well as the diode going intermittent and failing when a high current is passing through it.
You must remember also, a diode is made of materials that break-apart very easily. The only

thing that keeps them together is the body of the diode. If the body of the diode expands, the junction separates.

Now go to:

DIODE TEST

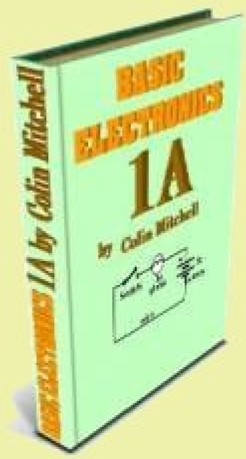
see also:

How a Capacitor Works

You will find a lot of helpful material on "electronics in general" on these pages:

Spot Mistakes: **P1** **P2** **P3** **P4** **. .** **P11** **P12** **P13** **P14** **P15** **P16** **P17** **P18** **P19** **P20**

Now go to Basic Electronics 1A:



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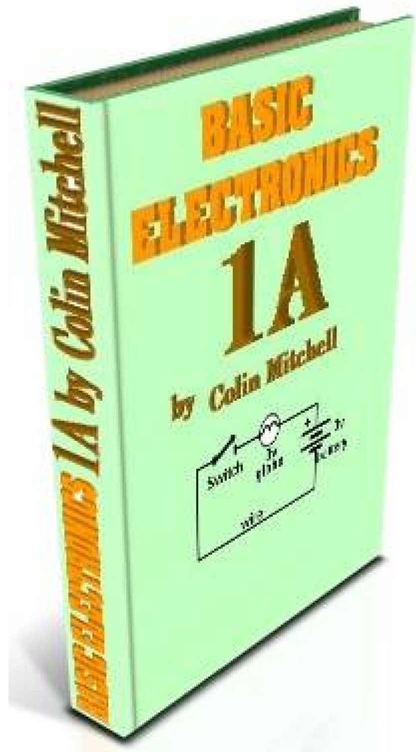

For any enquiries email Colin Mitchell

THE TRANSISTOR

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THE TRANSISTOR

In this section we will cover **THE TRANSISTOR.**

The transistor is a 3-leaded device that comes in many different shapes and sizes with hundreds of different voltage and current and amplification values and capabilities.
There are 20,000 different types and we are going to concentrate on just **TWO**.
They are called **NPN** and **PNP GENERAL PURPOSE TRANSISTORS.**
Their technical name is **BIPOLAR JUNCTION TRANSISTOR** to distinguish them from other types of transistor such as **Field Effect Transistor, Uni-Junction Transistor,** and other types.
The transistor we will cover is used in hobby circuits. It is the cheapest, simplest and most-common transistor and has one of the following identifications (according to the country of origin).

NPN types include: BC547, 2N2222. 2N3904, PN100, BC338, 2SC945, BC107, BC147, 9013
PNP types include: BC557, 2N3906, PN200, BC157, BC327, 9012, 9015

99% of circuits use **NPN** transistors and this is the type we will describe. The **PNP** type is called a "mirror image" and we will explain it also.
This narrows the field to one type of transistor and we will describe over 100 different ways to use it in a circuit.
Before we start, we will show you the "end product."
The following animation shows how a transistor works.
A drip entering the base (the funnel) will produce a "thump" from the speaker. A larger drop will produce a louder "thump."

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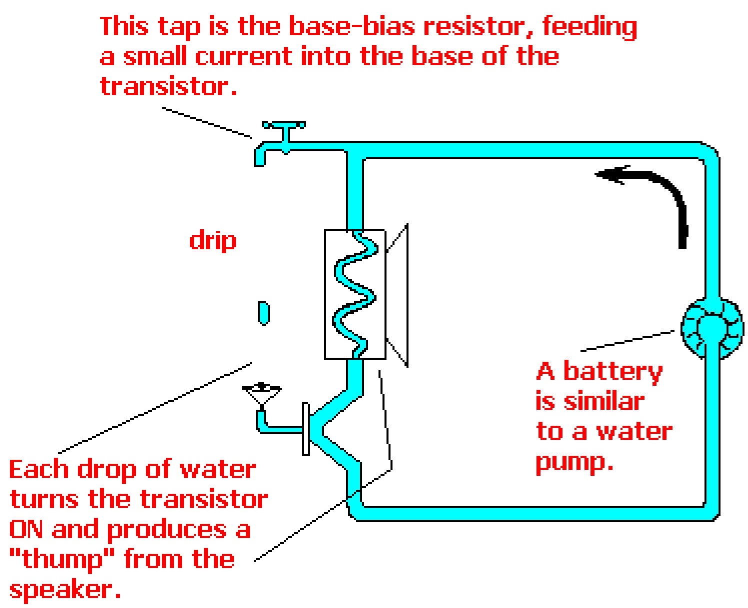

Fig 1. The WATER NPN TRANSISTOR

The animation shows a **WATER NPN TRANSISTOR.**

The drip represent a small amount of energy entering the base (in the form of a voltage and current).
This results in a larger current flowing in the speaker.

As the drip gets bigger, the "Thump" from the speaker gets louder.

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Here is a transistor animation from Williamson Labs:
http://www.williamson-labs.com/480_xtor.htm
It shows a transistor being turned on by more current flowing into the base and this makes the transistor "squeeze tighter and pulls the spring "down."

We will now explain

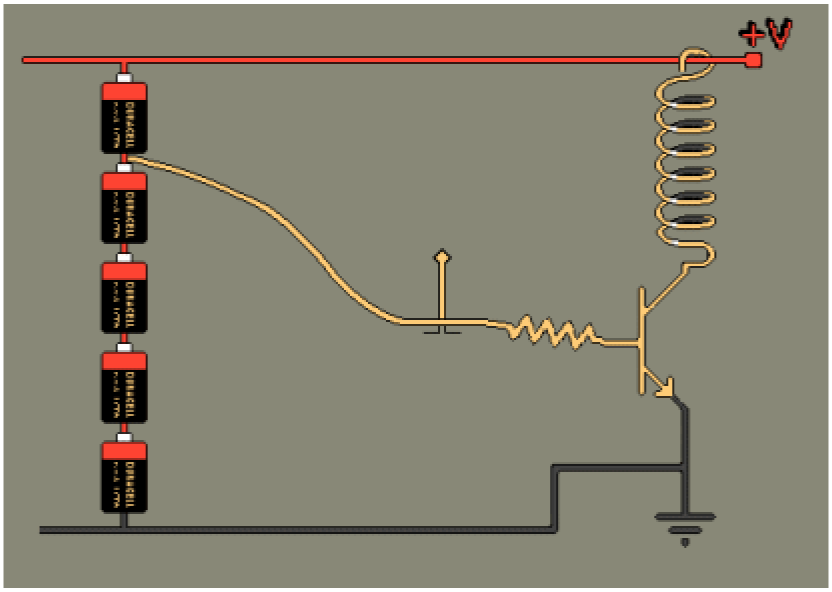

Fig 2. The SPRING TRANSISTOR

how a transistor works.

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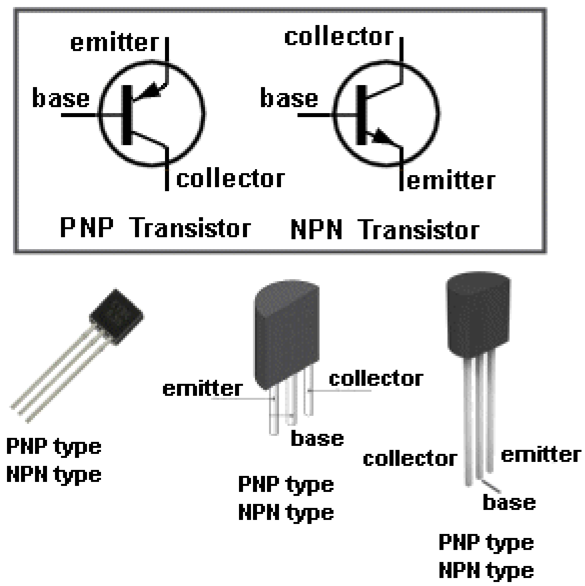

Fig 3. TRANSISTOR SYMBOL

The symbol for a PNP and NPN transistor are shown in the diagram. As you can see, PNP and NPN transistors look exactly the same. You need to identify them by the numbers on the side of the device or by testing them.
We have included a **Transistor Tester** in Fig 65 of the first section of the course.

The leads on a transistor can be:
emitter-base-collector
or
collector-base-emitter

and that's why you have to know what to do.

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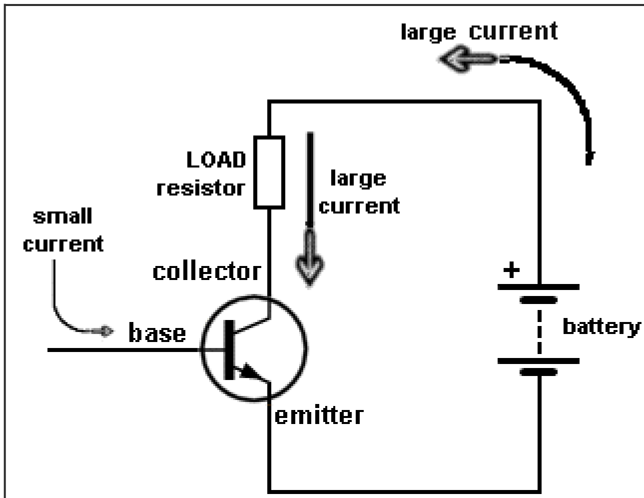

Fig 4. TRANSISTOR IN A CIRCUIT

The first type of transistor we are going to study is the **NPN**.
A transistor has three leads:
BASE, COLLECTOR and **EMITTER**
Basically, a small current enters the base and a large current flows through the collector-emitter leads as shown in the diagram.
The resistor in the collector lead is called the **LOAD** Resistor.
Sometimes the load is a speaker.

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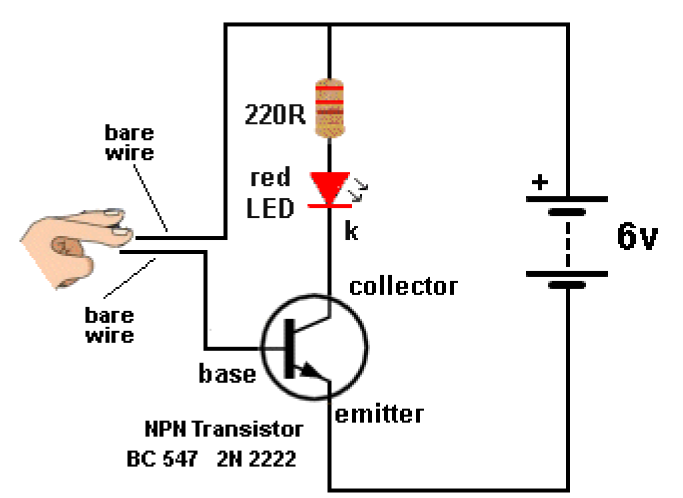

Fig 5. Turning ON a TRANSISTOR

Turning ON a TRANSISTOR
Here is a simple project to turn a transistor **ON**.
Touch the two bare wires with a finger and squeeze HARD.
Make sure the two wires do not touch as this will instantly damage the transistor.
The LED will illuminate very faintly as you press on the wires.
Your fingers allow current to flow through the two wires and into he base of the transistor.
The transistor amplifies this current and illuminates the LED. It will be very dull.

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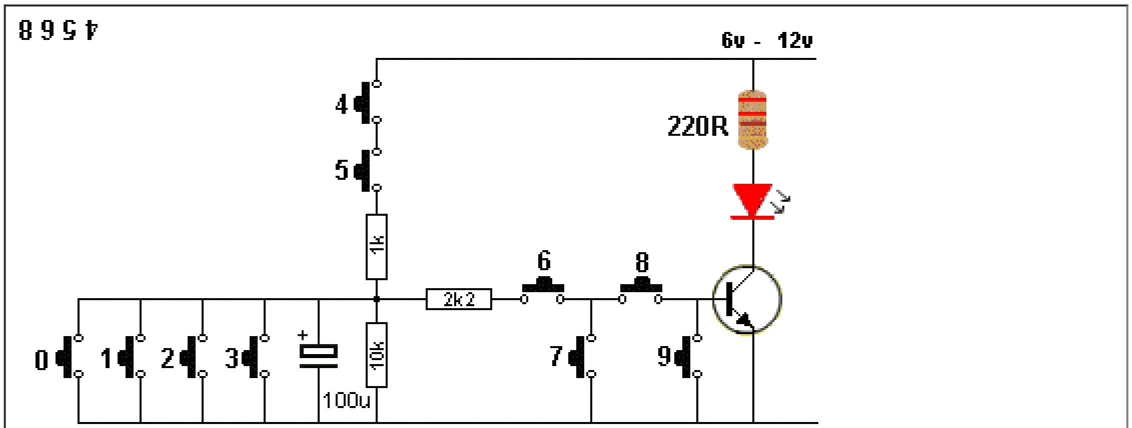

Fig5a. Which switches do you push (at the same time) to turn the transistor ON? (answer above)

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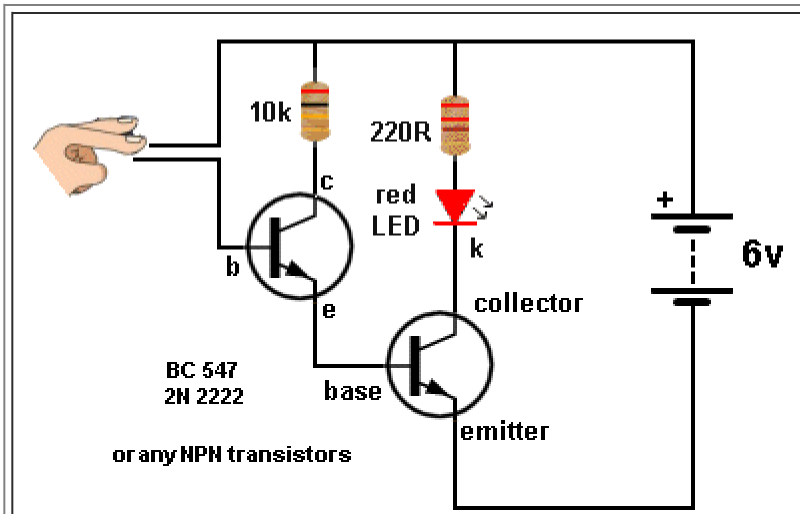

Fig 6. Two TRANSISTOR Circuit

By adding another transistor we amplify the current through the finger about 200 times and now the LED will glow bright.

The **ACTION** of the first transistor is to amplify the current through your finger.
This is sometimes called:
TRANSISTOR ACTION.
It means the amplifying action of a transistor.

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This circuit has enormous gain.
Each transistor has a

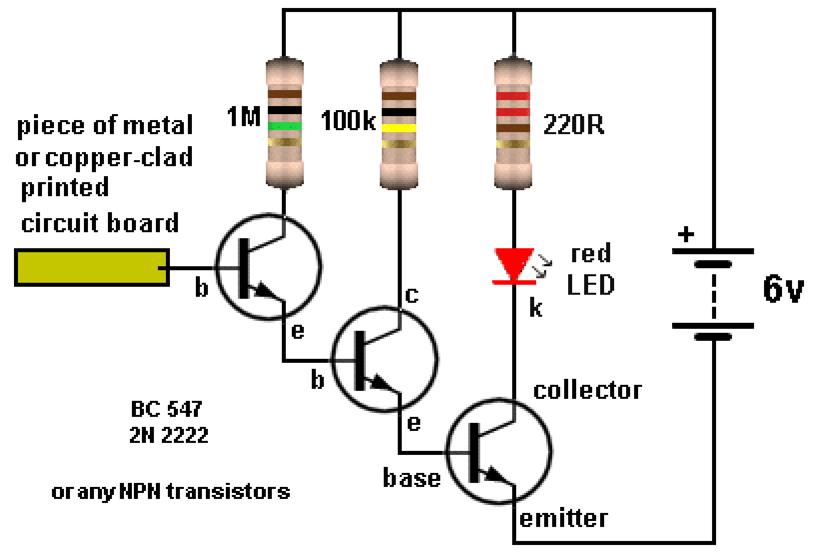
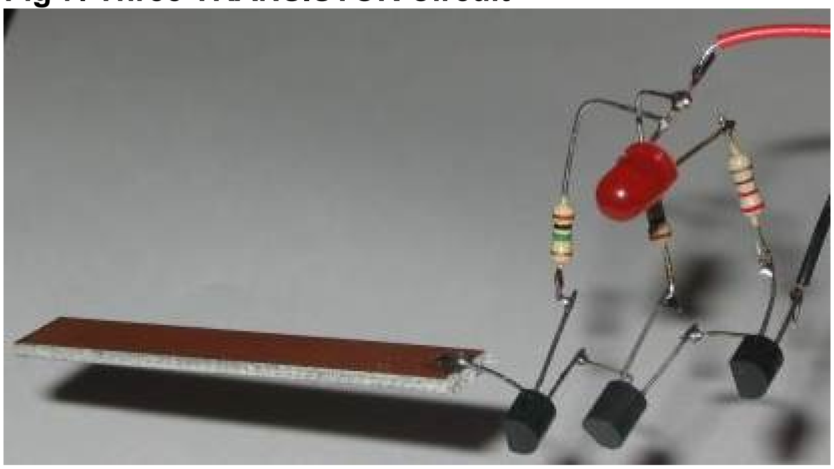


Fig 7. Three TRANSISTOR Circuit



gain or more than 200 and the final gain will be more than:
200 x 200 x 200 = 8,000,000
8 MILLION!

The circuit is very sensitive to static voltages in the air or electrical waves such as the waveform produced by the electrical wiring in a house.
Move the project around a room and detect all the electrical signals.

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The circuit above is very simple but it shows how to connect 1, 2 and 3 transistors to produce a circuit with enormous **GAIN**.
GAIN is the **AMPLIFICATION** provided by each transistor. Some call it: **TRANSISTOR ACTION.**
Turning **ON** a transistor is the most difficult part to understand so we will cover it in a completely new way.   The animation below shows the transistor turning ON when the base voltage reaches 0.65v.

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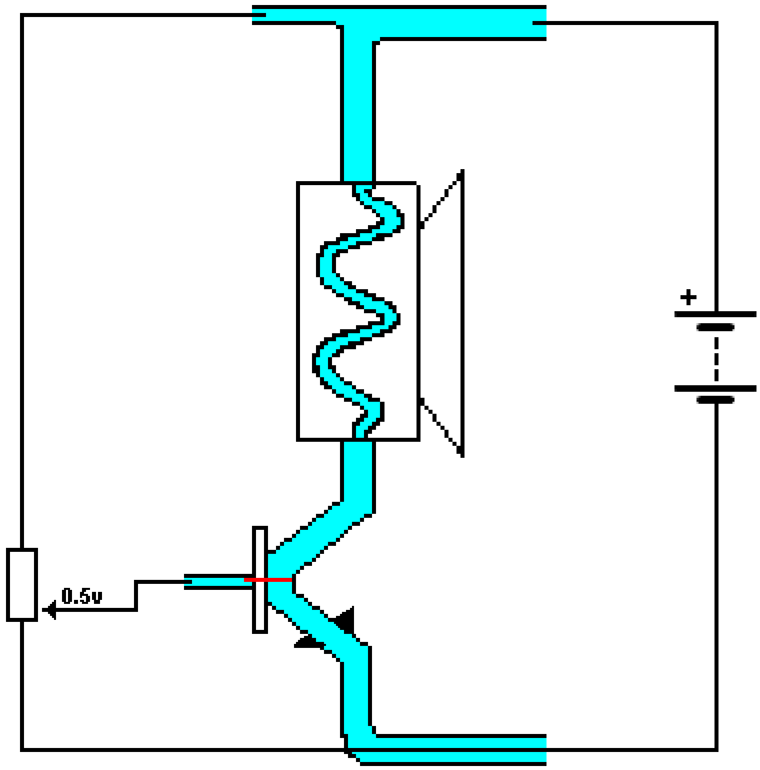

Fig 8. The Base turning ON a Transistor
The transistor does not turn on until the base voltage is 0.65v.
A small current into the base will produce a larger current-flow in the collector-emitter circuit.
As the potentiometer is raised, more current flows into the base and this causes more current to flow in the collector-emitter circuit.
The base voltage increases to a maximum of about 0.7v

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The two facts we have covered above are:
1. The transistor does not turn ON until the base voltage is 0.65v.
2. The collector-emitter current increases if the base current increases.

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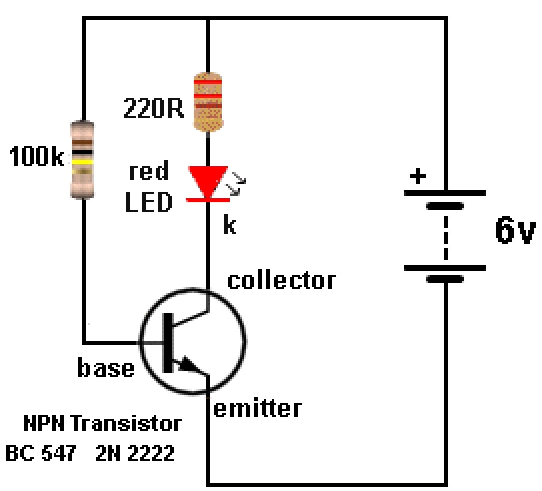

Fig 9. Base Bias

BASE BIAS
Instead of your finger turning ON the transistor (as shown in Fig 5 above), it can be turned on via a resistor.
This is called a **BASE BIAS** resistor.
Firstly it will provide the 0.65v to 0.7v for the base and secondly it will provide a current into the base.
The transistor will amplify this current about 200 times and the LED will illuminate.

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Here is a new concept
To work out how the circuit will respond to a 100k base-bias resistor, we divide the 100k

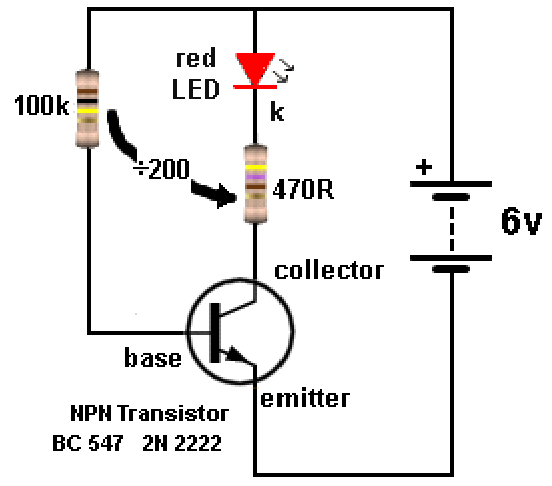

Fig 10. New Concept

by the gain of the transistor. We assume the gain of the transistor in this circuit is 200.
100k / 200 = 500 ohms Use 470R resistor.
This is a quick. easy. simply way to "see" a circuit working.
The gain of a transistor can be 150 to 300 in this circuit so no amount of mathematics is going to produce a better result.

Note: this concept works when the new value of **load resistor** is larger than the old load resistor.

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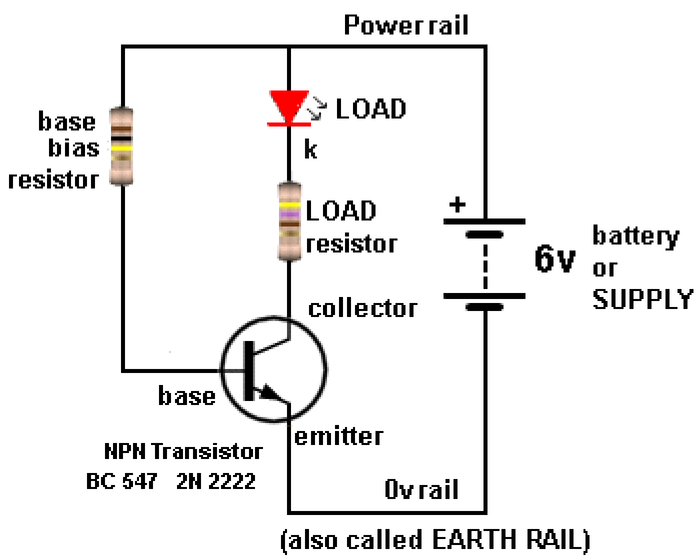

Fig 11. Circuit Names

The name of each component is identified in this figure.

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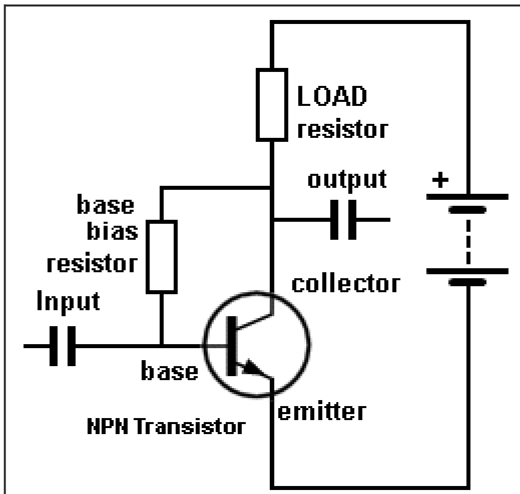

Fig 12. The self-biased Transistor

The self-biased Transistor

The self-biased transistor is an amplifier stage consisting of a transistor, base bias resistor, load resistor input capacitor and output capacitor.
It is called a **STAGE** because it has its own input and output capacitor and its own biasing.
The capacitors prevent any DC biasing on one stage from affecting the biasing of another stage.
In other words, this stage is self-contained.

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How the self-biased Transistor Works

When the circuit is turned ON, the transistor is not conducting and the base sees a voltage and

current via the base-bias resistor and LOAD resistor.
This turns the transistor ON. Current flows through the collector-emitter terminals and the same amount of current flows through the LOAD resistor. This creates a VOLTAGE-DROP in the LOAD resistor and the voltage on the collector drops. This means the voltage across the base bias resistor is reduced and this reduces the current into the base of the transistor.
This causes the transistor to turn OFF slightly.
The transistor settles to a condition where the current through the base-bias resistor allows say 200 times more current to flow in the LOAD resistor. A voltage develops across the load resistor to produce a condition called the **QUIESCENT** condition or **IDLE** condition or **DC CONDITION**.
The value of the two resistors are chosen so the voltage on the collector is mid-rail.
This allows the transistor to amplify both the positive portions (excursions) of the input waveform as well as the negative portions.

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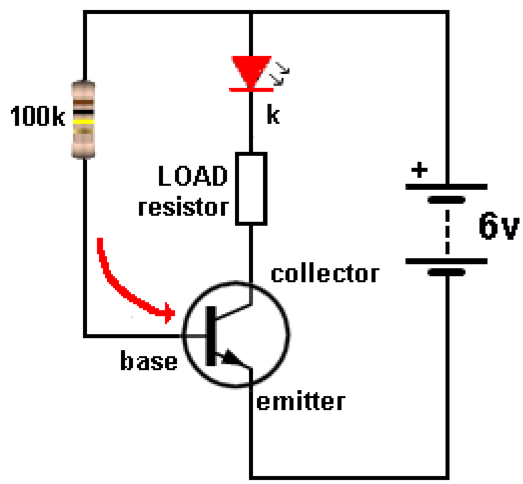

Fig 13. HOW MUCH CURRENT IS FLOWING?

HOW MUCH CURRENT IS FLOWING?

The current-flow into the base can be worked out by **Ohm's LAW**

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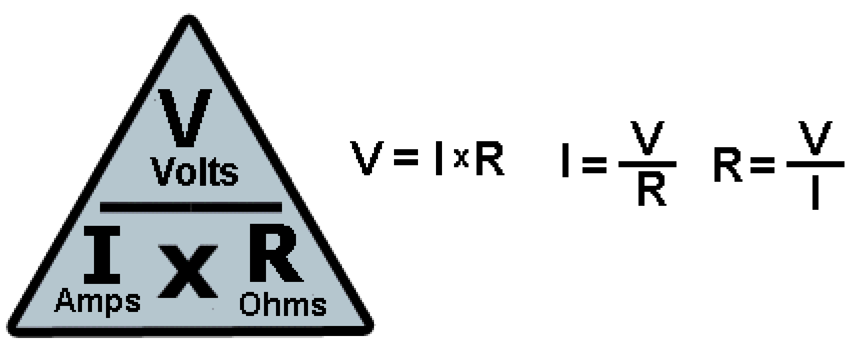
OHM'S LAW

Ohms Law is a simple equation that connects **VOLTS, AMPS and RESISTANCE.**

VOLTAGE is measured in **VOLTS**
CURRENT is measured in **AMPS and**
RESISTANCE is measured in **OHMS**

OHM'S LAW TRIANGLE



Cover the letter you want and the other two values appear in the correct place in the equation.

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In the circuit above we know the value of voltage and resistance, so the equation is:

$$I = \frac{V}{R}$$

$$= \frac{6v - 0.7v}{100{,}000}$$

$$= 0.053mA$$

If the transistor can amplify this current 200 times, the collector-emitter current can be about 0.053 x 200 = 10.6mA

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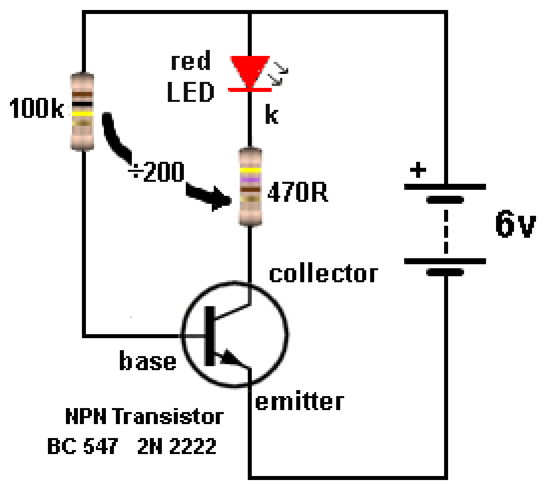

Fig 14. LOAD Current

The transistor is capable of delivering 10.6mA through the collector-emitter circuit but let's look at what the 470R will deliver.

$$I = \frac{V}{R}$$

$$= \frac{6v - 0.2v - 1.7v}{470}$$

$$= 8.7mA$$

You can see the complexity of the mathematics. That's why we will simplify the maths.

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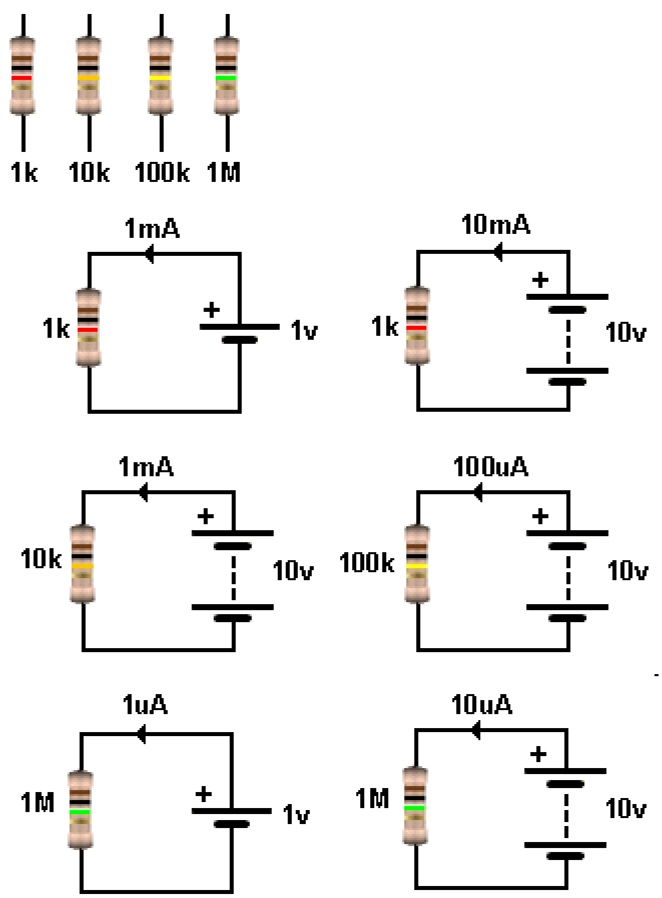

Here is an easy was to work out the current flowing through a resistor.
In the first circuit, a resistance of 1k will allow a current of 1mA to flow when the voltage is 1v.
If the voltage is 10v, the current will be 10mA.
For a 10k resistor, when the voltage is 10v, 1mA will flow.
For a 100k resistor,
100 microamp will flow when the voltage is 10v.
For a 1M resistor, the current will be 1uA for 1v supply and 10uA for 10v supply.

Fig 15.Simple Mathematics

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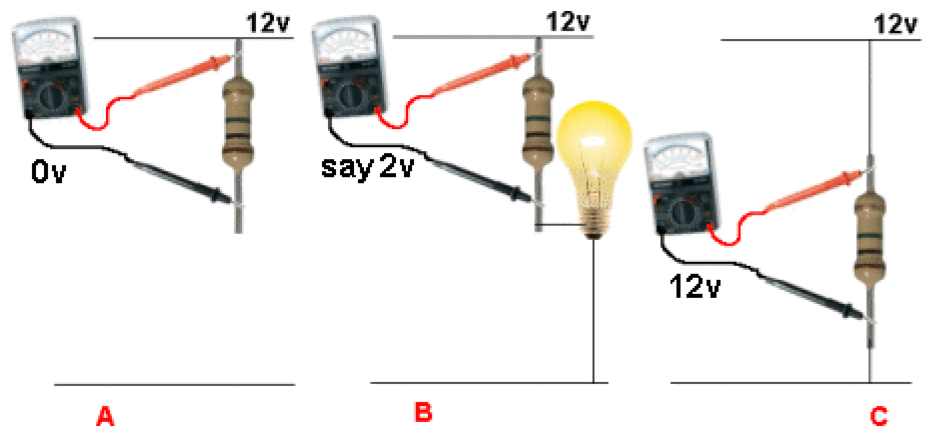

Fig 16. Voltage Drop

In our discussions we have talked about a LOAD resistor and when current flows through a resistor a voltage is developed across it.
In circuit A, the resistor is not connected and no current flows and it is not a load resistor (at the moment).
The globe in circuit B has a load resistor. The voltage across the resistor may be 2v, (depending on the value of the resistor). If a high voltage is developed across the resistor, the globe will not be very bright.
In circuit C the resistor is connected across the rails and 12v will be across the resistor.

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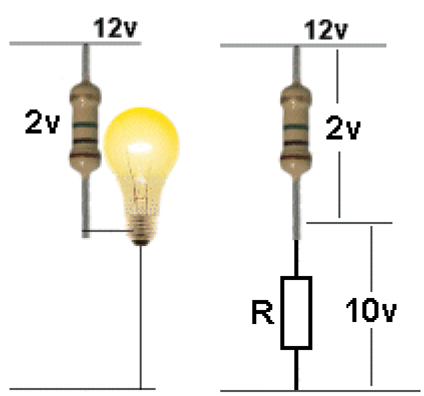

Fig 17. The Voltage Divider

In circuit B above, the resistor will have 2v across it and the globe will have 10v across it. The globe can be considered to be a resistor and thus we have two resistors in SERIES as shown in the diagram on the left.
The 12v is divided between the two resistors. It does not have to be divided equally.
But the voltage across the top resistor plus the voltage across the bottom resistor must equal the voltage of the supply.

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A voltage divider can be two or more resistors in SERIES or a resistor and globe, or two globes or a resistor and a transistor.

The base-bias resistor R forms a voltage divider with the base-emitter junction.
The LOAD resistor R2 forms voltage divider with the collector-emitter terminals of the transistor.

Any two or more items in **SERIES** will produce a **VOLTAGE DIVIDER**.

The **CURRENT** (in Amps) through the top component will be the same as the current through the bottom component.

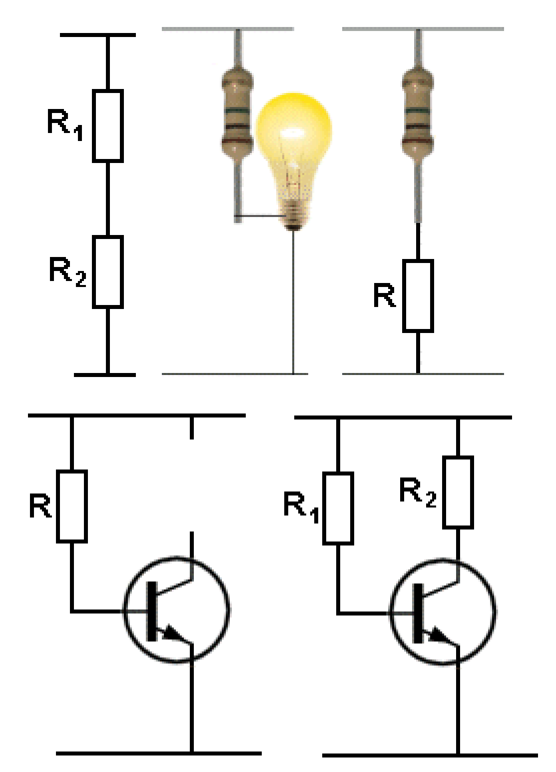

Fig 18.Types of Voltage Divider

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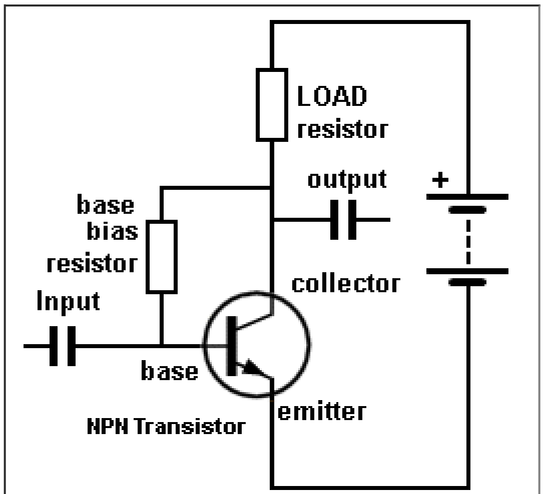

Fig 19. The STAGE

The circuit shown is called a "**STAGE**."
A Stage is a set of components (generally including a transistor) that is separated by a previous stage by a capacitor and has a capacitor on the output.
A capacitor does not allow DC (Direct Current) to pass through it and this really means the voltage on a previous stage is not passed to the stage we are analysing.
This means the voltage on or across each of the components is due to the biasing of the components in the stage we are analysing.
Ideally the collector should be at half-rail voltage and this is called the "idle" or "standing" or "quiescent" conditions.

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The voltage on one side of a capacitor may be 3v and 6v on the other side. The 3v can drop to 0v slowly and the 6v will not change. A capacitor does not pass DC.
But if a 3v signal is delivered to one side of a capacitor, the signal will pass through and appear on the other side.
The signal will be reduced a small amount but the main point to note it will **PASS THROUGH THE CAPACITOR**.
This is how an audio signal passes through an amplifier, from one stage

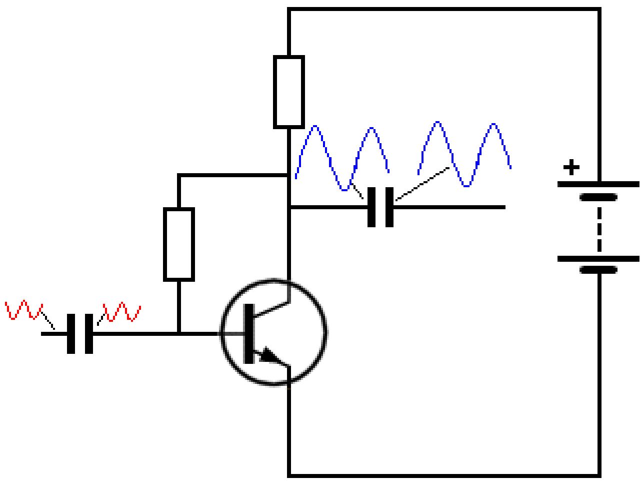

Fig 20. Signal Through A Capacitor

the next and is amplified by each stage.

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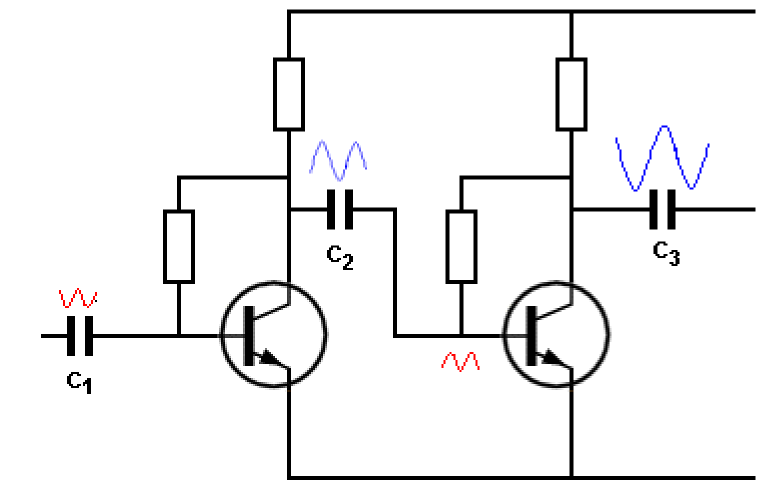

Fig 21. AC Coupling Two Stages

Combining the information we have learnt, we can combine two stages and show how the signal is amplified through two AC coupled stages.
Each stage consists of a self-biased transistor with a capacitor at the input and output.
This type of coupling is called **AC COUPLING** because it will only pass AC signals.
It is also called **RC Coupling** (Resistor-Capacitor coupling) and it only passes AC signals - fluctuating signals - rising and falling signals.

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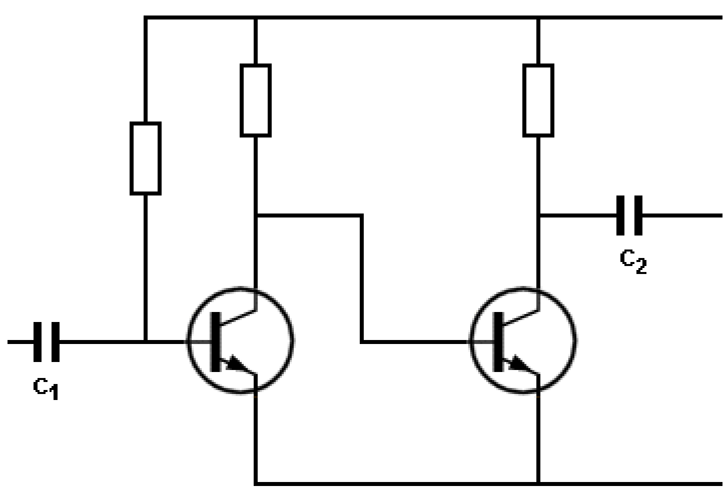

Fig 22. DC Coupling two Stages

Two stages can be DIRECTLY CONNECTED as shown in the circuit above.
This is called **DIRECT COUPLING** or **DC COUPLING**.
DC actually stands for **Direct Current**. This sounds unusual, but it is the way to explain the circuit will pass (amplify) **DC voltages** and that's why we say they are **DC COUPLED**. This type of coupling will pass both **AC signals and DC voltages.**

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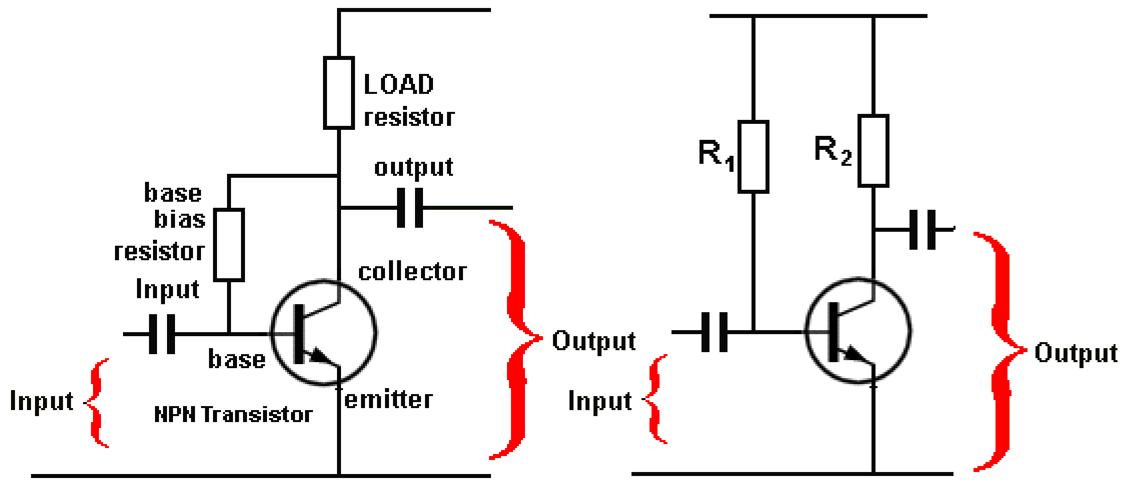

Fig 23. The Common Emitter Stage

The STAGES above are a **COMMON EMITTER STAGE** because the emitter is connected to the 0v rail and the input uses the base and the emitter and the output uses the collector and emitter, making the emitter COMMON to both the input and output.

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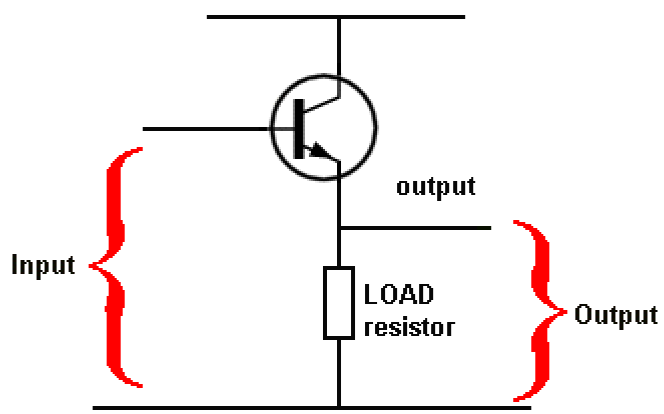

Fig 24. The Common Collector Stage

The common Collector Stage is also called **Emitter Follower Stage.**

The **COMMON COLLECTOR STAGE** has the collector connected to the top supply rail and the input an output is shown on the diagram.
The top SUPPLY RAIL and the 0v rail connect to a battery or some other source of voltage and the resistance between the two rails is very small.
That's why the input between the base and 0v rail can also be considered to be between the positive rail and base. The output can be considered to be between the emitter and positive rail. The collector is connected to the positive rail and it is effectively COMMON to the input and output.

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The **COMMON COLLECTOR STAGE** takes a weak input signal and delivers a strong output.
See animation.
The output can be abut 100 to 200 times stronger.
The output voltage is the same as the input voltage but the **CURRENT** is increased.
The emitter follows the voltage on the base ants why it is called

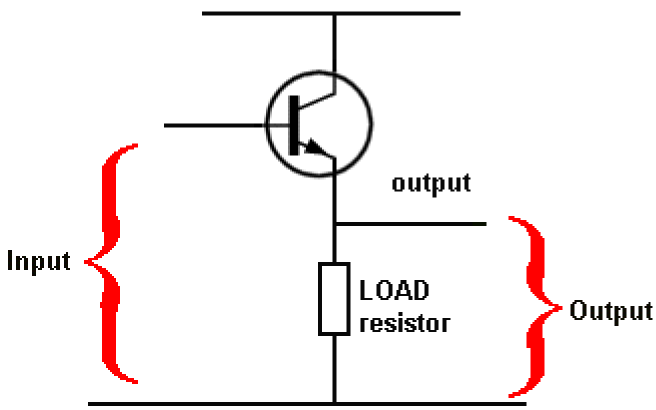

Fig 25. The Common Collector Stage is STRONG! **The output is 100 - 200 times stronger than the input.**

an **EMITTER FOLLOWER stage**.

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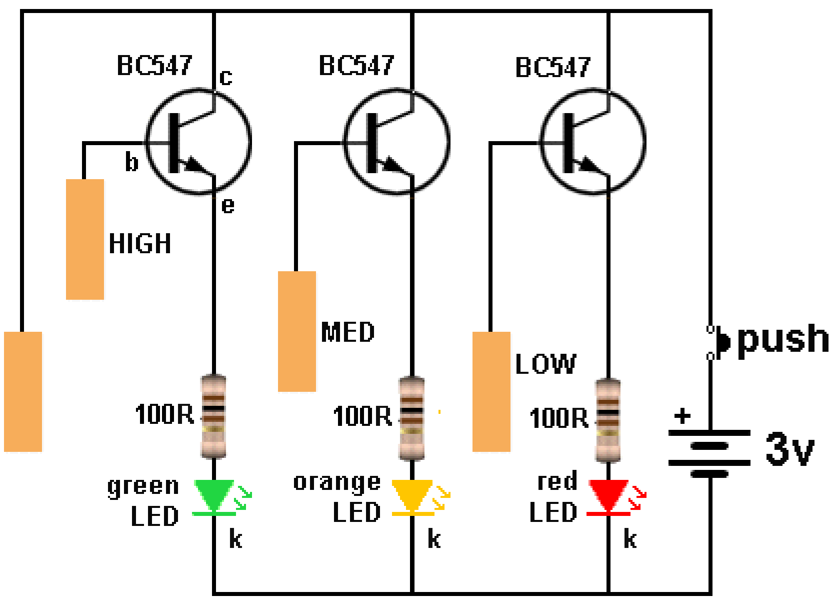

Fig 25a. Water Level Detector
Here is a circuit using an **EMITTER-FOLLOWER** stage to illuminate a LED when two probes detect water. There are three levels, High, Medium and Low.
Water has a resistance and when water touches the High pad and the pad on the left it is just like the Base-Bias Resistor shown in the circuits above.
The base-bias resistor turns ON the transistor and the base rises. The emitter "follows" and it rises too. This puts a voltage on the emitter which is passed through the 100R to the LED.
There are three separate identical circuits to show when the water tank is full, half-full and near empty.
Pure water has a very high resistance but the minerals in tap water make the water conductive.
Build the circuit and see the LEDs illuminate. You can see them gradually come ON as the water rises.

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A weak input signal can be converted to a strong signal by using an **EMITTER FOLLOWER** transistor to drive a speaker.
The transistor amplifies the strength of the signal by a factor of about 100 times.
The amplitude of the signal is not increased, just its ability to drive

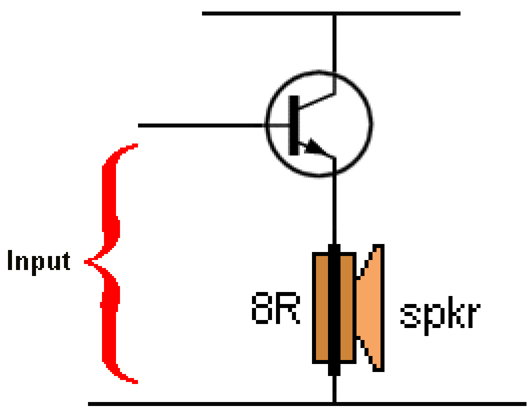

Fig 26. Driving a Speaker

a current through a LOAD (the speaker).

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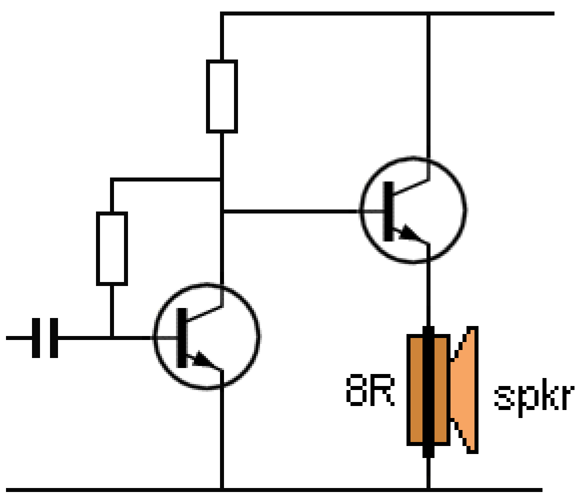

Fig 27. Connecting two Stages

The circuit shows how to connect two stages to drive a speaker.
A speaker is a very low impedance (resistance) device and a weak signal will not create any output.
The first stage is a self-biased common-emitter stage that will increase the amplitude of the signal about 100 times and also increase its strength.
The second stage takes the amplitude of the signal and delivers the same amplitude but with an increased strength of about 100 times.

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What is a SIGNAL?
A Signal is an input voltage.
It may be the signal from an electret microphone, an audio waveform, or the resistance of your finger or a sinewave from a generator.
In all these instances we have described the amplitude of a signal. The amplitude is the VOLTAGE of the signal.
But a signal consists of a VOLTAGE and comes with a value of CURRENT. This current may be very small (such as from an electret microphone) or it may be very high (such as from a switch).
In most cases we do not talk about the value of current associated with the signal.
At this point we will simply say that ALL signals come with a VALUE OF CURRENT. And this is called "The Power of a SIGNAL." In other words: The STRENGTH of a Signal" or the "Driving capability of a signal.
We can say a signal is "very weak" or "delicate" or "strong" or "has good driving capability."
Some signals will drive a LED or speaker while others need to be amplified before they can be used.
In most cases the "driving power of a signal" is unknown. It is not provided as a specification.
And yet its value is MOST IMPORTANT. In most cases you cannot work out the current-capability of a signal by looking at the device generating the signal.
That's why we are showing how to amplify a signal so that it is strong enough to drive an output device.
This is a very complex area of discussion and we will introduce it slowly.

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There are 3 more points we can cover with this circuit.
Amplifying circuits are designed

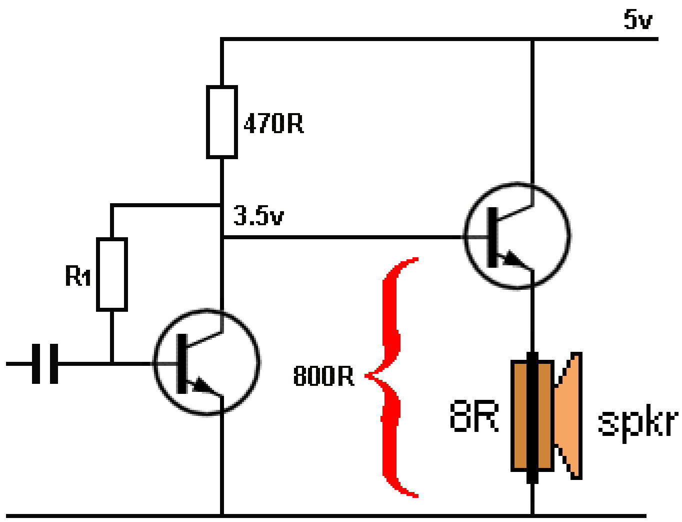

Fig 28. Voltages on the Circuit
(This circuit is only to show how to connect stages together. It is NOT a good design as you will see later in the course.)

backwards. They are designed from the output to the input.
In this circuit the output is 8 ohms.
The emitter-follower has a gain of about 100 and this means the impedance of the speaker is reflected to the base by a value of 8 x 100 = 800 ohms.
The load resistor for the self-biased transistor must be 470 ohms so the voltage on the collector will be higher than mid-rail voltage.
The value of R1 can be 1M to 2M2 as the transistor is held at mid-rail by the second transistor and R1 will only be used to supply turn-on voltage for the base of the first transistor.

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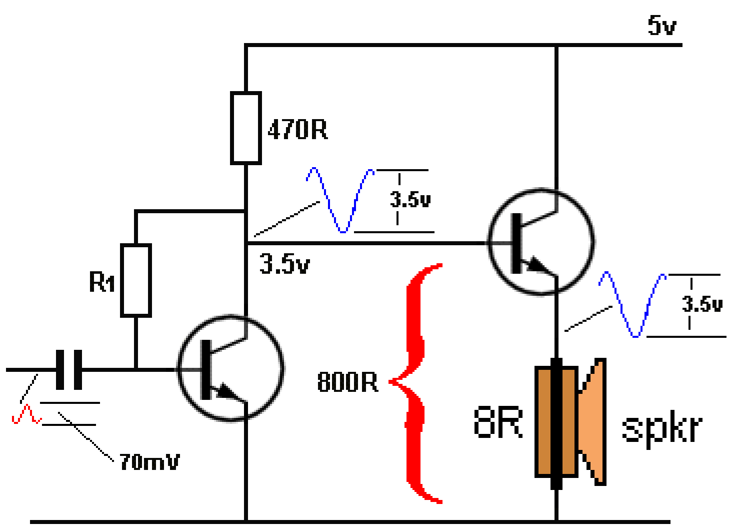

Fig 29. Signal Amplification

If the first transistor has a **GAIN** of 50, a 70mV input signal will produce
70 x 50 = 3500mV (3.5v) signal on the collector.
The second transistor will pass this 3.5v signal to the speaker with a "current capability" of 100 times greater than the signal on the collector of the first transistor.

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The next set of circuits use both NPN and PNP transistors, so we need to explain how a PNP transistor works.
Basically it is a "mirror image" of an NPN transistor and is added to a circuit "up-side-down."
The arrow on PNP transistor points to wards the base and follows the direction of current.
The **Base Bias Resistor** allows a small current to flow via the base and this creates a large current-flow though the emitter-collector terminals (emitter-collector junction).

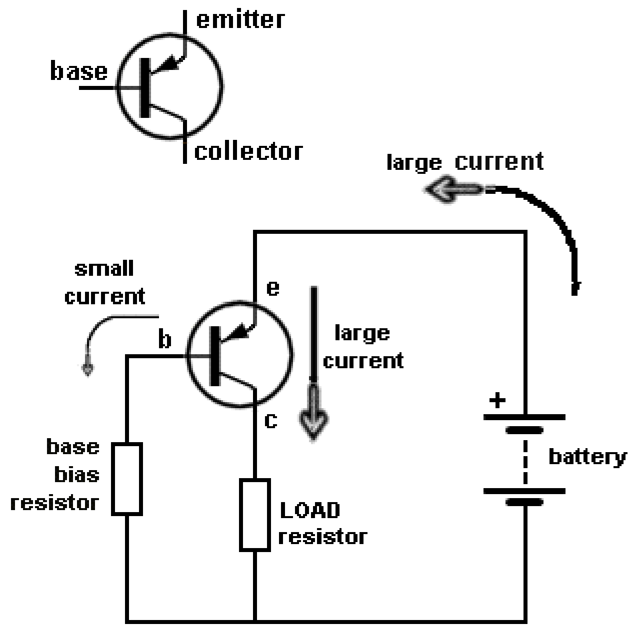

Fig 30. The PNP Transistor

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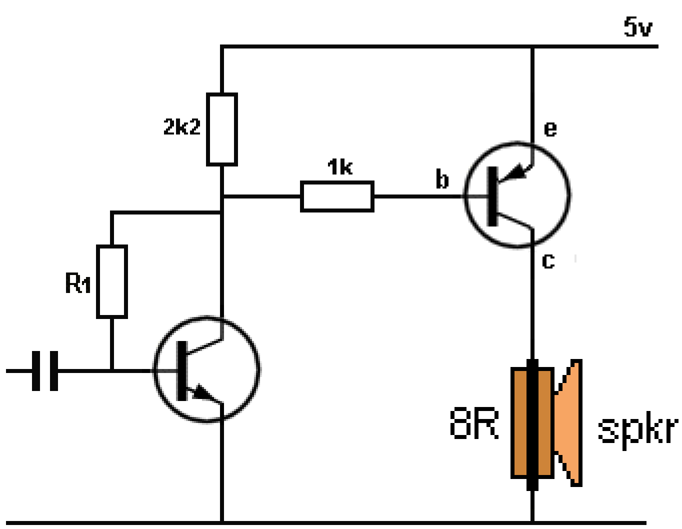

Fig 31. Connecting NPN to PNP

The speaker circuit in **Fig 29** can be built with an **NPN** and **PNP** transistor, as shown opposite.

The 1k resistor is called a "stage separating resistor" or "stage joining resistor" or "current limiting resistor."
It performs all 3 tasks.
It joins the to stages and limits the current through the emitter-base junction of the PNP transistor and collector-emitter junction of the NPN transistor when both transistors are turned ON.

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If we connect a capacitor to the circuit in **Fig 31**, an amazing thing happens.
The circuit turns into an **OSCILLATOR.**
The circuit is actually a high-gain amplifier with **POSITIVE FEEDBACK.**
It introduces 3 new features.
Feedback can be POSITIVE or NEGATIVE.
Positive feedback takes a signal from the output of a circuit to an input and the result increases the amplitude of the signal on the input.

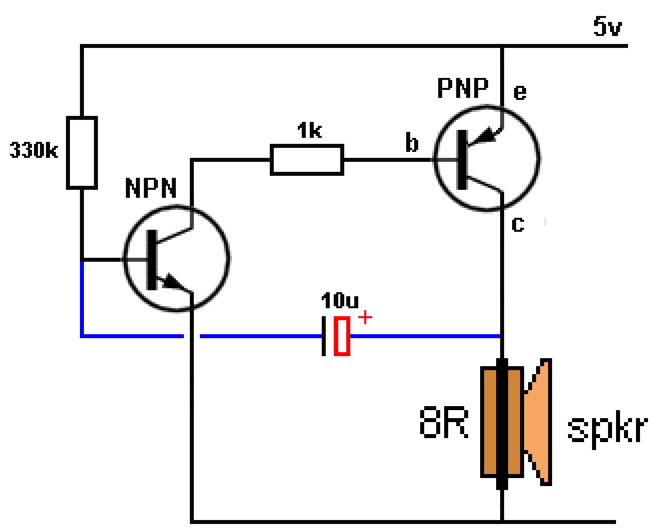

Fig 32. Creating an OSCILLATOR

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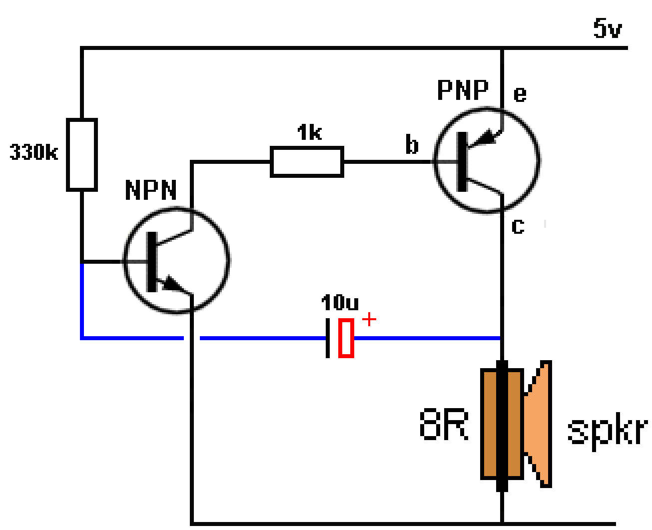

Fig 33. How the OSCILLATOR works

The 10u discharges through the base-emitter of the NPN and gets charged again via the 330k to start the next cycle.

The animation shows how the 10u charges via the 330k and when the voltage on the base of the NPN transistor is 0.65v, it turns ON and this turns on the PNP transistor via the 1k resistor.
The collector of the PNP transistor has about 3-4v on it and this makes current flow through the speaker to produce a "click."
The positive lead of the 10u is taken HIGH and it starts to charge via the base-emitter junction of the NPN transistor.
When it is nearly charged, the NPN transistor turns off slightly and this turns off the PNP transistor and the voltage on the collector falls slightly. This is passed to the base of the NPN transistor to turn it off slightly and the two transistors very quickly fully turn OFF.

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The animation does not show the full complexities of how the oscillator works and one of the points to understand is the charging of the 10u.
At the beginning it gets charged in the reverse direction by the 330k and when the base of the NPN sees 0.65v, it starts to turn ON.
This causes the PNP to turn ON and the collector pulls the top of the speaker towards the positive rail. This action pushes the charge on the 10u into the base of the NPN transistor because the positive lead of the 10u rises and raises the negative lead. This immediately turns the NPN on MORE and very quickly both transistors are fully turned ON.
As the positive lead of the 10u rises a point is reached where the 10u changes from pushing its charge into the base to a point where it starts to charge in the forward direction because the positive lead is now higher than the negative lead.
During this time the current continues to flow into the base and that's why the NPN continues to stay fully turned ON.
As the 10u charges, the current starts to decrease and a point is reaches where the flow of current into the base does not k\keep the NPN fully turned ON.
The NPN starts to turn OFF slightly and this is passed to the positive lead o f the 10u. The 10u "drops" slightly and this very quickly turns OFF the NPN and and the PNP.

They both turn off fully and now the base is a few volts lower than the 0v rail.
The 330k starts to remove the charge on the10u and eventually charge it to 0.65v to turn on the NPN to start the next cycle.

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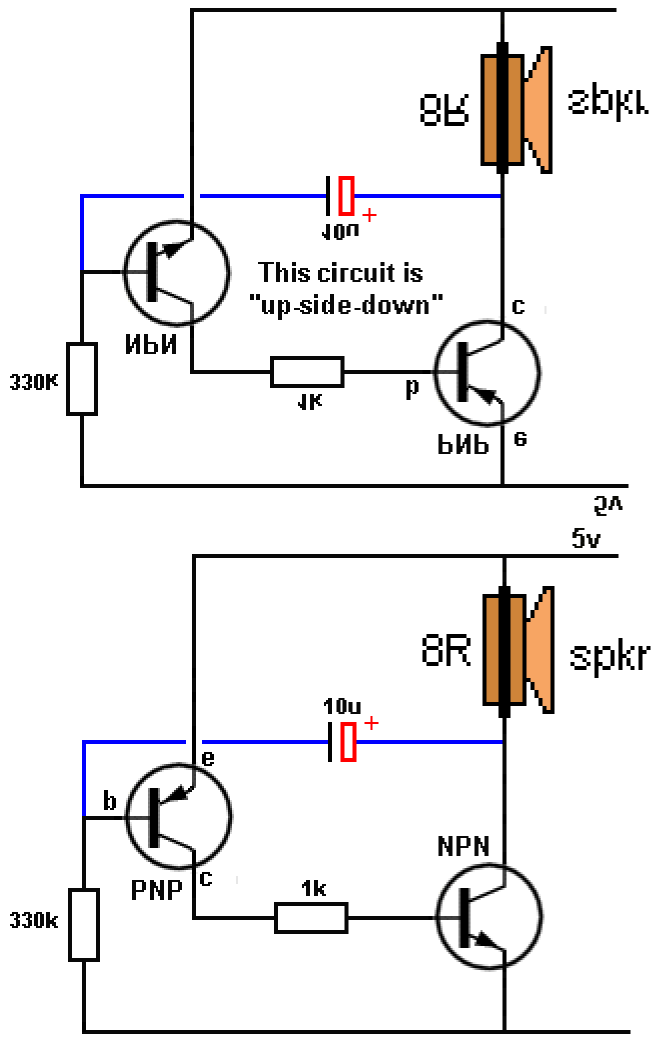

Fig 33a. INVERTING A CIRCUIT

An NPN transistor is a mirror image of a PNP transistor.
The circuit above can be "turned over" as shown opposite and the PNP transistor changed for NPN and the NPN transistor changed for PNP.

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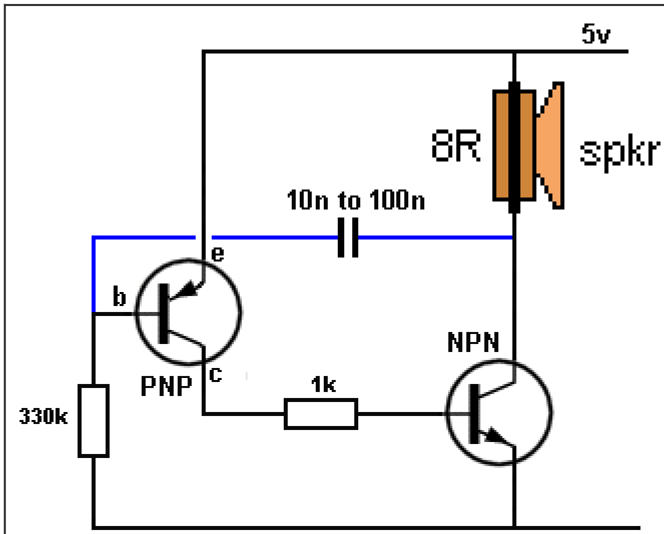

Fig 33b. Changing the Frequency

The frequency of the circuit can be increased by replacing the 10u electrolytic with a 10n to 100n capacitor.

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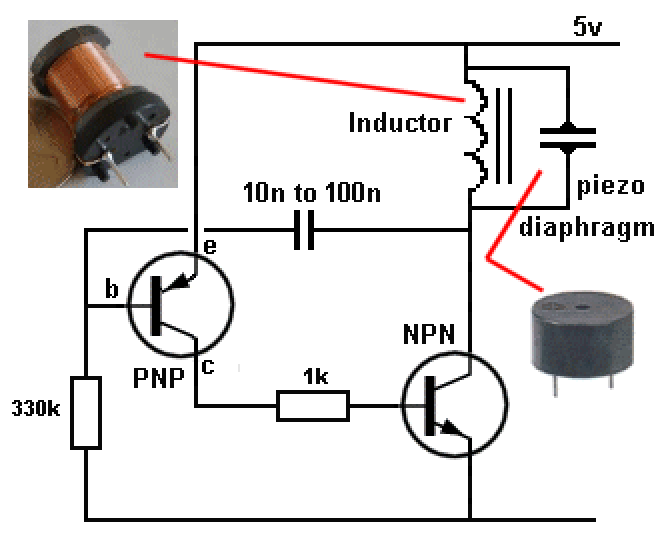

Fig 33c. Adding an INDUCTOR

If we replace the speaker with an inductor an amazing thing happens. The inductor is just like a speaker but it has more turns and the effect we will be observing will be INCREASED.
To hear what the inductor does, we put a piezo diaphragm across it.
The piezo diaphragm detects voltage.
When the circuit it is turned ON the squeal from the piezo is VERY LOUD, indicating the inductor has increased the voltage.
An inductor is a coil of wire wrapped around a core made of iron or similar material.
It is also called a **CHOKE** or **COIL**.

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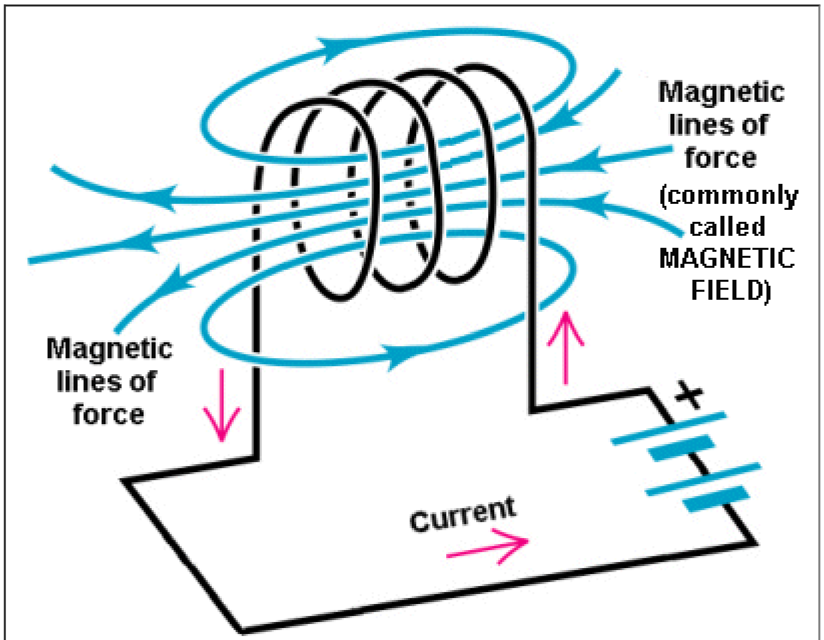

Fig 33d. Magnetic Lines of Force produced by an Inductor when a current flows

When current flows through an Inductor Magnetic Lines of Force are created.
The Inductor is turned into an
ELECTROMAGNET
and it will pick up small nails and pins.
But in the circuits we are describing, the amazing thing is when the inductor is turned OFF.
It produces a very HIGH VOLTAGE when it is turned OFF.
This voltage is due to the rapid collapsing of the magnetic field.

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The animation shows the coil receiving a small positive voltage via the switch and when the switch is released, the coil (inductor) produces a very large voltage in the opposite direction.

The most important part of this animation shows the **REVERSE VOLTAGE** produced by the Inductor.

This is refered to as **BACK EMF** or **FLYBACK VOLTAGE** and is one of the most important facts to remember as it will allow you to understand how many circuits work.

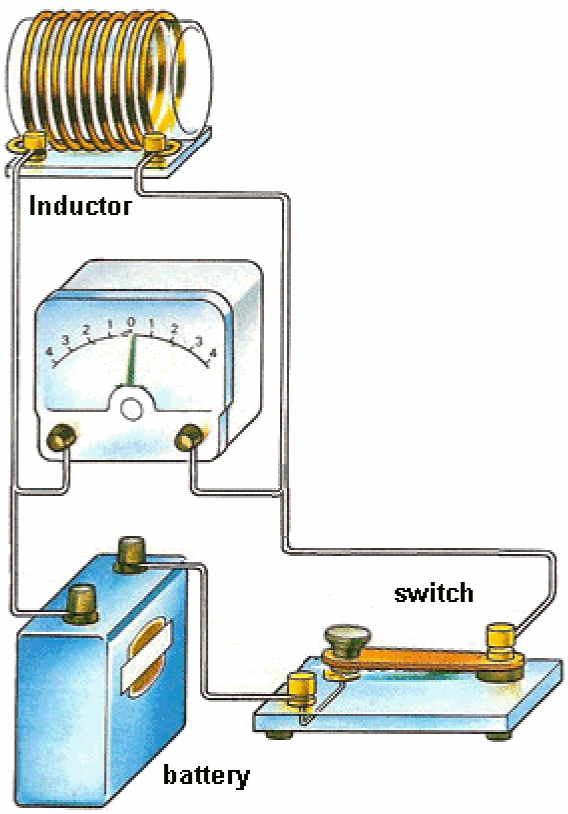

Fig 33e. Back Voltage - commonly called FLYBACK VOLTAGE

It explains how a reverse voltage is produced in many circuits to illuminate LEDs etc.

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We have shown how components such as capacitors and coils can COMPLETELY change the operation of a circuit. These components appear to be very simple but the way they work is very complex.
For example a capacitor can detect the **change in voltage** on one part of a circuit and send this change to another part of the circuit. This is commonly called **FEEDBACK** and can be **POSITIVE FEEDBACK** or **NEGATIVE FEEDBACK**.
A capacitor can do more than 10 other things, depending on where it is placed and it size.
A coil (inductor) is more complex than you think. It can also perform more than 10 different effects, depending on its size and where it is placed.
If another coil of wire is placed on top of the first coil, it becomes a **TRANSFORMER** and this will be discussed later.

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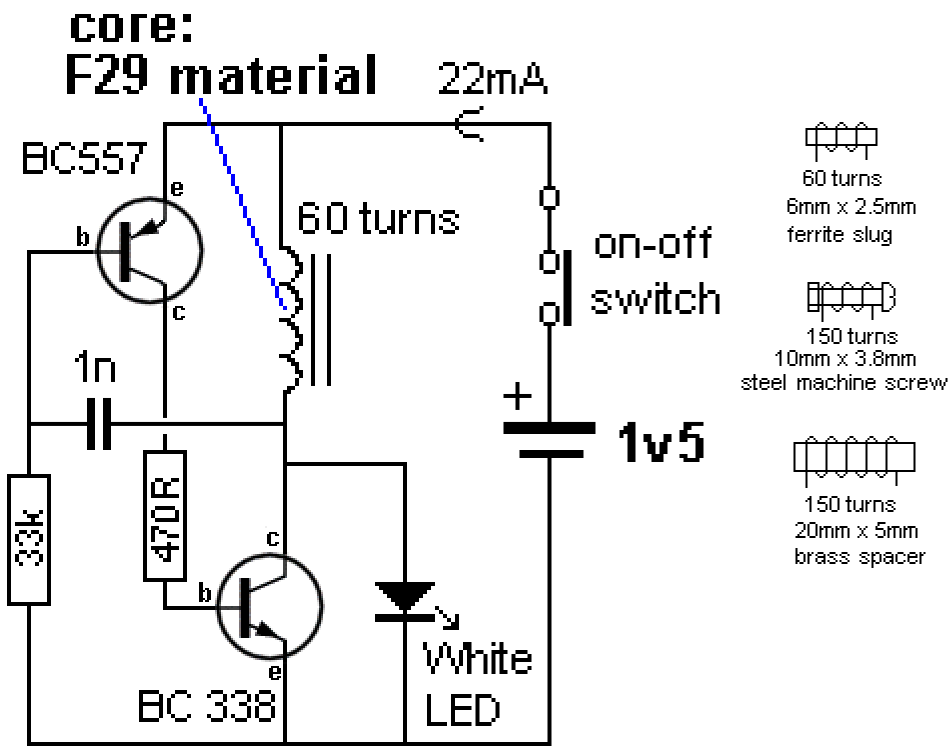

WHITE LED DRIVER

Fig 33f. Flyback Circuit

Here is a circuit that will illuminate a white LED from a 1.5v supply. We know a white LED needs 3.6v to illuminate so the added voltage must come for the "back voltage" produce by the coil. The 60 turn inductor is wound on a small ferrite slug 2.6mm dia and 6mm long with 0.25mm wire. The main difference between this circuit and the two circuits above is the use of a single winding and the feedback to produce oscillation comes from a 1n capacitor driving a high gain amplifier made up of two transistors.

The feedback is actually positive feedback via the 1n and this turns on the two transistors more and more until finally they are fully turned on and no more feedback signal is passed though the 1n. At this point they start to turn off and the signal through the 1n turns them off more and more until they are fully turned off.

The 33k turns on the BC557 to start the cycle again.

If you do not have a ferrite slug, the inductor can be made from a machine screw 10mm long and about 3-4mm dia. Wind 150 turns of 0.25mm wire. Or you can use a brass ferrule 20mm long x 5mm. Wind 150 turns.

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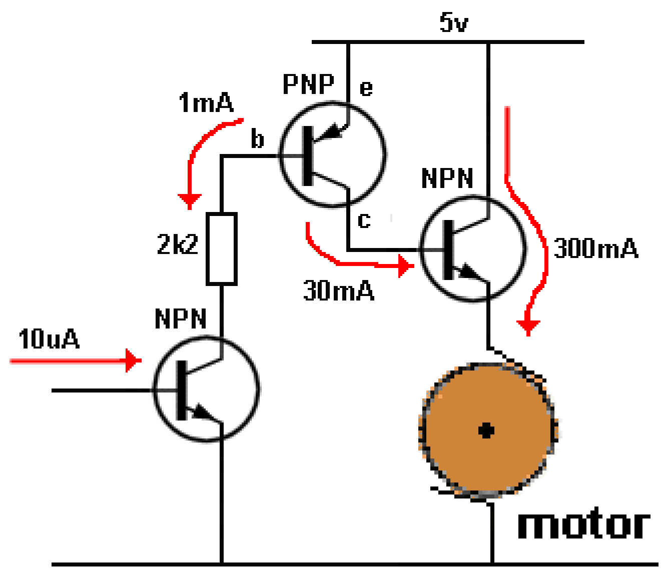

Fig 34. Driving a Motor

We can combine the last three stages we have covered and combine them to produce a circuit to drive a motor.
A circuit to drive a motor needs a high current on the output.
This circuit takes a very weak input signal of 10uA and amplified it via the first transistor, about 100 times to provide 1mA base current for the second transistor. The second transistor amplifies the current abut 30 times to provide 30mA for the emitter-follower and the output of this transistor will deliver about 300mA to the motor.

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The 3 stages above are **DC COUPLED** to each other and any signal above 0.65v on the input of the first transistor will turn it ON. 10uA is a very small current so that almost any signal will activate the circuit.
The 2k2 resistor limits the current through the emitter-base junction of the PNP transistor and 1mA is enough to turn it ON fully.
The PNP transistor will deliver at least 30mA to the base of the third transistor and this will provide more than 300mA for the motor. The current taken by the motor will depend on the loading of the motor and the circuit must be able to deliver this current.

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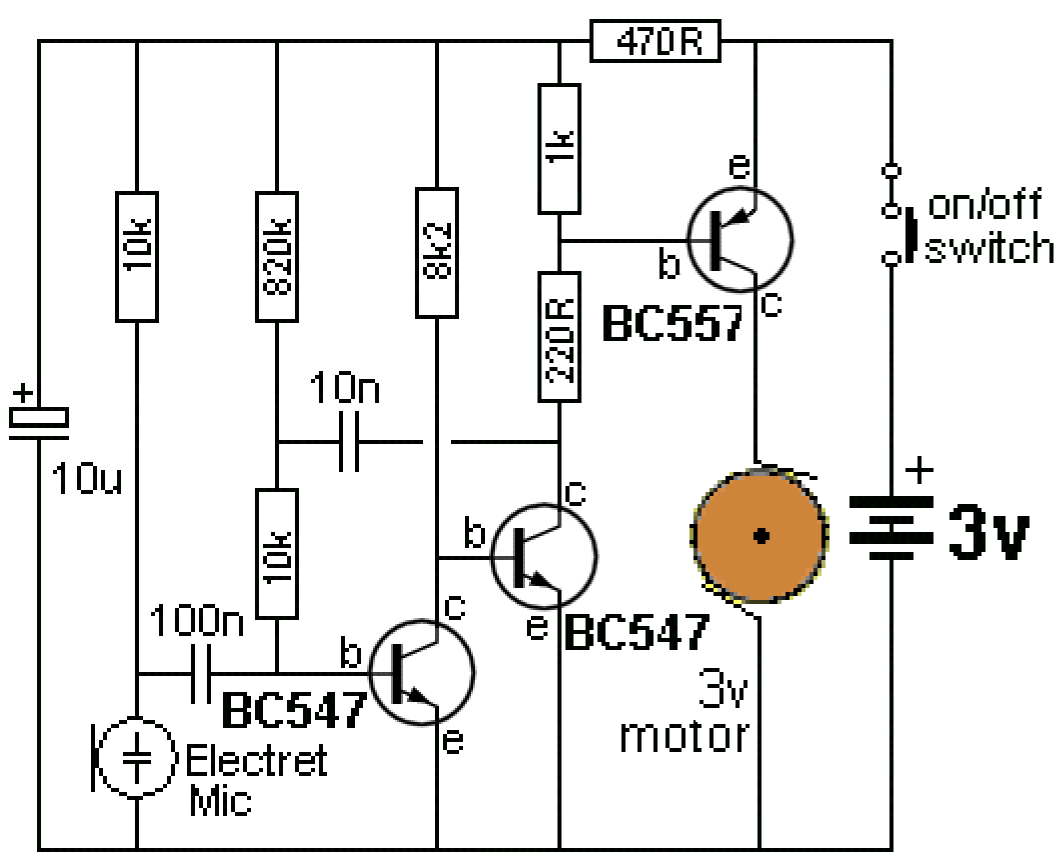

Fig 35. Dancing Flower

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Dancing Flower

Here is a practical circuit using the "building Blocks" we have covered.
The second and third transistors form the high-gain amplifier described in Fig 31 and the first transistor is a **COMMON EMITTER STAGE** described in Fig 23.
But we have an added component. A 10n capacitor. We have already explained that a capacitor can provide **FEEDBACK - POSITIVE FEEDBACK**
and that is what this capacitor does.
The capacitor does not make the circuit oscillate but it provides a feedback pulse that turns the circuit ON FULLY when a small pulse is received from the electret microphone.
A small negative waveform through the 100n will turn the first transistor off slightly and the collector voltage will increase. This will turn on the second transistor slightly more and the collector voltage will drop. This will be passed to the right lead of the 10n capacitor and the left lead will also drop. This will put a lower voltage on the base of the first transistor and it will turn off more.
At the same time, the lower voltage on the collector of the second transistor will be passed to the base of the third transistor to turn it ON and the increased voltage on the collector will spin the motor.
The 10n will gradually charge and the first transistor will turn ON and this will turn OFF the second transistor and the motor will stop.
Music picked up by the electret microphone will make the motor start and stop to make the flower wiggle.
The motor is slowed down via a gearbox and a shaft is passed up the stem of the flower. The shaft is bent so that when it rotates, the flower dances like a hoola hoola dancer.

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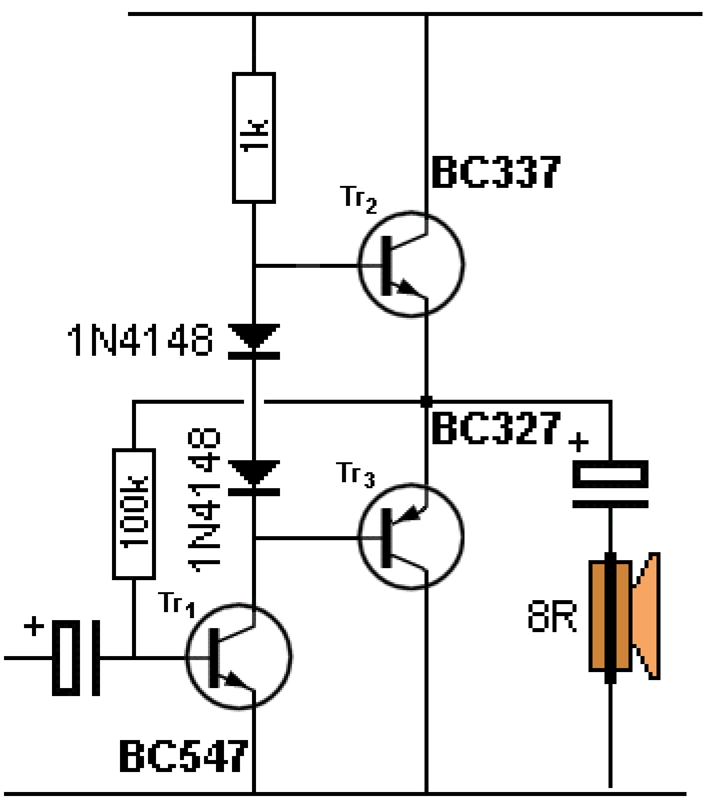

Fig 36. Push-Pull
You will recognise some of the sections of this circuit, but the transistors work in a slightly

different way to the previous circuits we have described.
The new items are the diodes.
Both the diodes are "turned ON" and conducting. The voltage across each diode is 0.65v.
The voltage across a base-emitter junction of a transistor needs to be about 0.7v for the transistor to be conducting. This means the diodes are at the point of just preventing the transistors turning ON.
When the BC547 receives a negative signal, it turns OFF and the 1k resistor pulls the BC337 towards the top rail and the emitter-follows and pulls the positive of the electrolytic HIGH. This starts to charge the electrolytic and the charging current flows through the speaker.
When the BC547 receives and positive signal, it turns ON and pulls the base of the BC327 towards the 0v rail and the emitter follows and pulls the positive lead of the electrolytic towards the 0v rail. This discharges the electrolytic and the discharge current flows through the speaker in the opposite direction to move the cone in the opposite direction.
At the same time the two diodes pull the base of the BC337 towards the 0v rail and it gets turned OFF.
The circuit is called **PUSH PULL** because it pushes the energy in the electrolytic through the speaker and then pulls then pulls the energy from the electrolytic via the speaker.
The current and voltage of the incoming signal is increased by the first transistors and the other two transistors only increase the current-capability of the signal.
The **PUSH PULL** section is also called a **COMPLEMENTARY-SYMMETRY** output stage.

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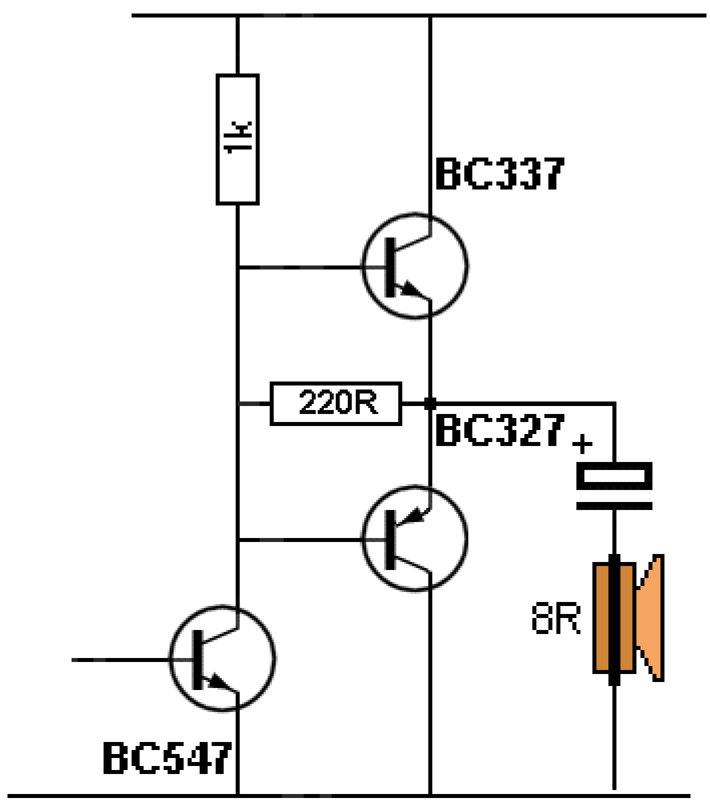

Fig 37. Current Dumping

Fig 37 shows a very clever variation of the Push-Pull circuit described above.
It uses a low-value resistor between the collector of the driver transistor and output.
This resistor transfers the low-level signals directly to the speaker. As the signal-level increases, the output transistors come into operation.
This arrangement removes cross-over distortion and uses less parts.
It is called **CURRENT DUMPING.**

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The transistor can be used in two different types of circuits.
ANALOGUE CIRCUITS
DIGITAL CIRCUITS
When the transistor is in an **Analogue Circuit**, we know it will be amplifying signals that are slowly rising and falling - such as audio signals.
We say it is an analogue transistor so we are ready to expect the voltages and waveforms on the base and collector when

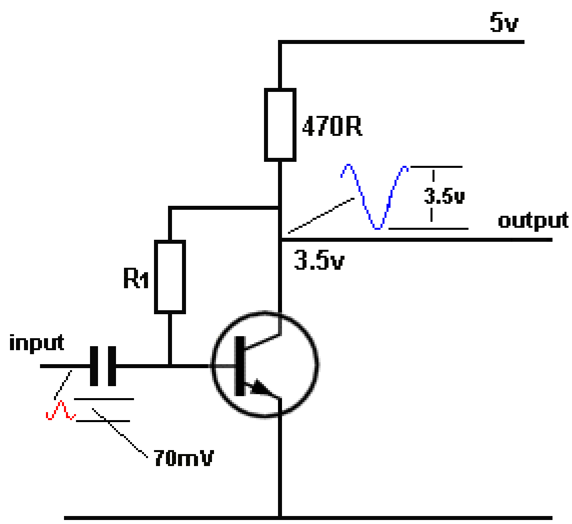

Fig 38. The Analogue Transistor

making tests.

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DIGITAL ELECTRONICS

Digital Electronics revolves around circuits that are either **ON** or **OFF**. In other words they are in a **HIGH** state or **LOW** state.

Go to the **DIGITAL** section of the course for more on this topic.

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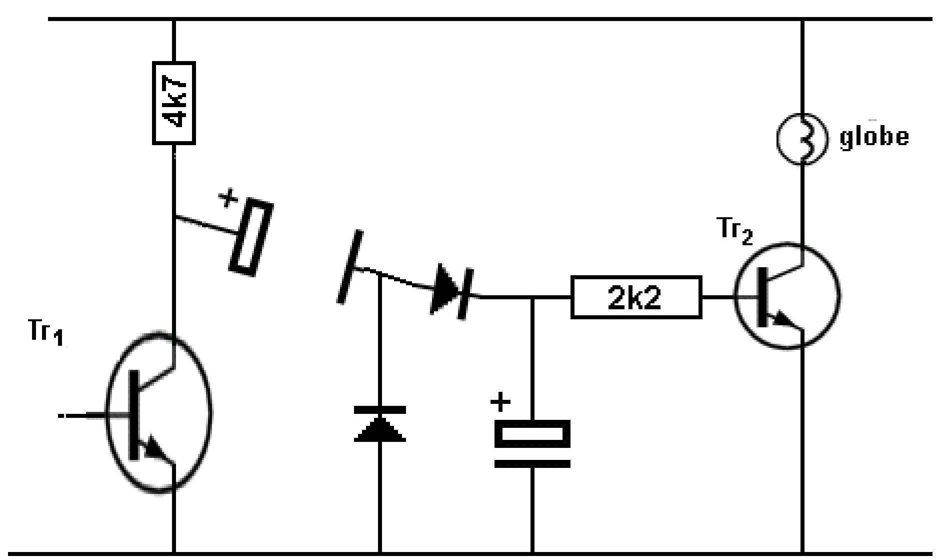
THE CHARGE PUMP

This circuit has a number of names and uses the amplitude of a signal to charge a capacitor. The voltage on the capacitor is applied to the base of a transistor and the transistor turns on a LED, relay, globe or motor.



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HOW A TRANSISTOR TURNS ON

When a transistor turns **ON**, it is just like a resistor having a **smaller and smaller** value of resistance. But the way it works in a circuit and the "effect" on other components can be different. Here are animations to show how a transistor can be turned **ON**:

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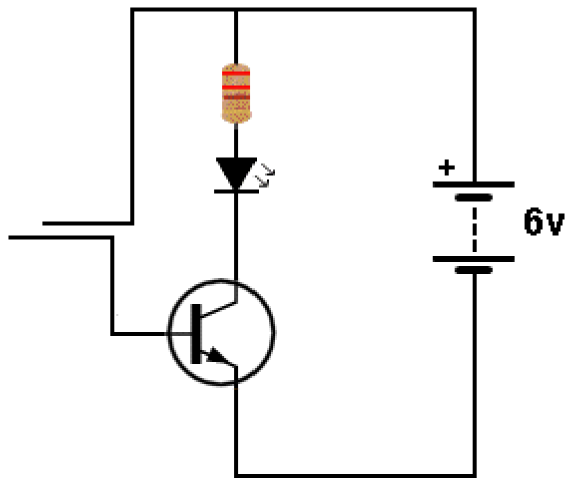

SIMPLE AMPLIFICATION

The finger is just like a resistor. As you press harder, the resistance gets smaller and the transistor turns **ON** more.
This is because more current flows from the positive rail and into the base of the transistor. The transistor amplifies this current and allows more current to flow in the collector-emitter circuit. The LED is in the collector-emitter circuit and it gets more current. This makes it glow brighter.

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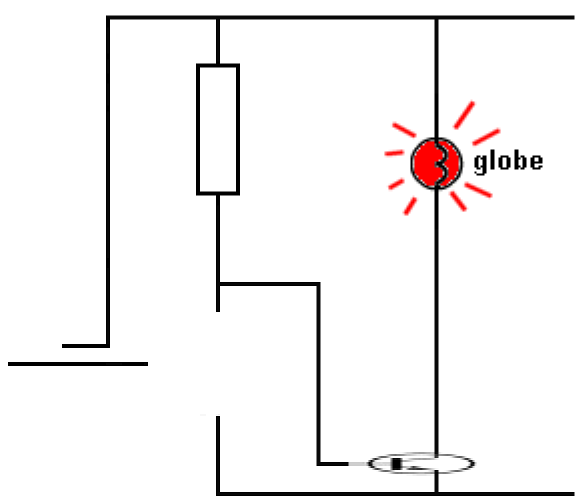
CUT-OFF and SATURATION

In this animation we see the first transistor turning OFF the second transistor. This action will be covered in more detail in the TRANSISTOR chapter.
At the moment, we just need to see is it possible to turn **ON** a transistor via a finger and this transistor will turn **OFF** the second transistor because it "robs" (takes away) the 0.6v (the base voltage) needed to start to turn **ON** a transistor.
The second transistor is receiving two different signals. The first signal consists of a voltage above 0.6v and current from the LOAD resistor to turn it **ON** (it is **SATURATED**). After the finger is applied, the second signal consists of a voltage less than 0.6v and the transistor is **CUT-OFF** (does not work). (There is no regeneration or feedback in this circuit.)



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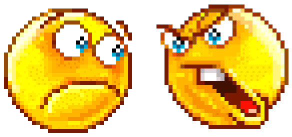
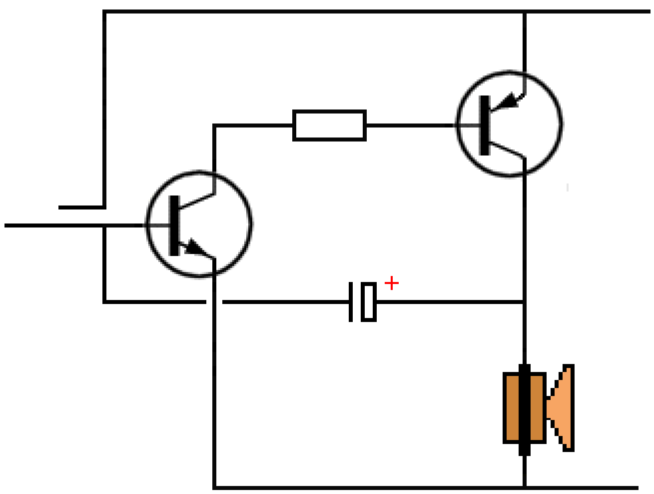
REGENERATION due to FEEDBACK

When two transistors are connected so one transistor turns **ON** the second transistor and the second transistor **FEEDS-BACK** to the first transistor to turn it **ON MORE**, the action is called **REGENERATION**.
It is just like "face-slapping." It starts with a slight slap, and it gets stronger and



stronger until both transistors are **FULLY TURNED ON**.
Regeneration can apply to a single transistor where a percentage of the output is fed back to the input to increase the amplitude of the signal or it can apply to two transistors where the feedback is provided by a capacitor (electrolytic).
Regeneration is a feature called **POSITIVE FEEDBACK** and the circuit turns itself **ON** more and more. Generally it only requires a very small signal to start the action.

This animation shows how a finger starts to turn **ON** the first transistor. The first transistor turns **ON** the second transistor and the output of the second transistor is FED BACK to the first transistor to turn it **ON** more.
You can see the finger is removed very quickly and the action continues due to **FEEDBACK**.
The circuit is a **HIGH GAIN DC AMPLIFIER** with **POSITIVE FEEDBACK**.
At the moment we are only interested in seeing how the circuit keeps turning itself **ON** more and more . . .



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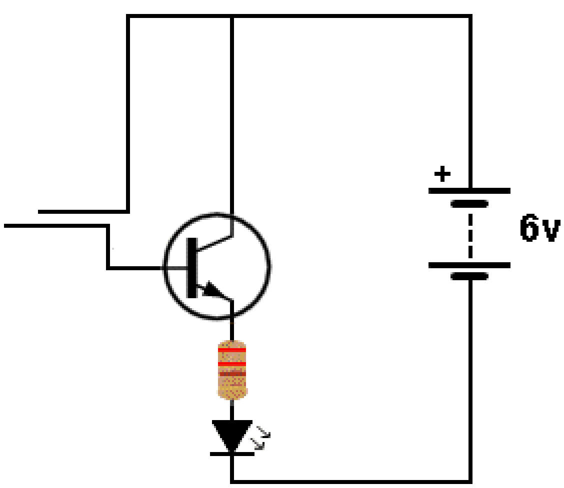
TURNING ON an EMITTER-FOLLOWER

When a LED is in the emitter lead of a transistor, it will be illuminated when a finger touches the wires shown in the following animation:



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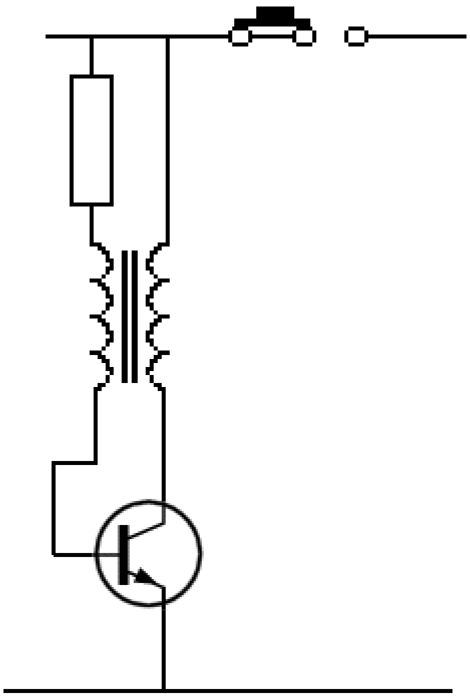
FEEDBACK via a TRANSFORMER

A transistor can be turned on via a positive **FEEDBACK** winding of a transformer. This is a

winding that supplies voltage (and current) to turn the transistor **ON** harder.
The transformer turns the transistor **ON** fully then IMMEDIATELY stops turning it on.
This is one of the amazing features of a transformer when connected as shown in the diagram and you will learn more about this in the course.
At the moment, we are only describing the **TURN ON** of the transistor and the fact that as soon as it is fully turned ON, the transformer stops turning the transistor ON. This is because the expanding flux suddenly stops when the transistor is fully turned **ON** and the feedback winding ceases to supply energy to the base.



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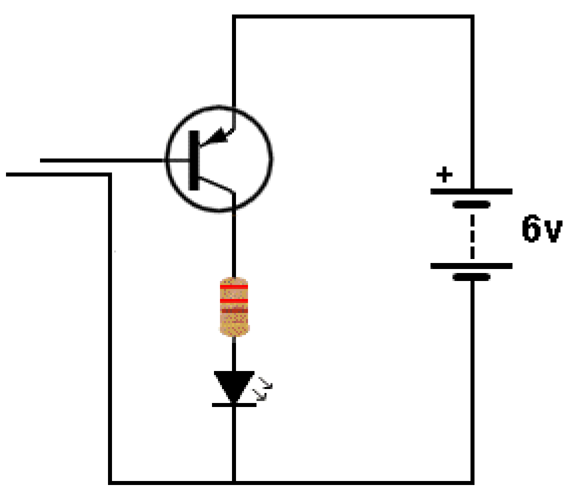
PNP TRANSISTOR

A PNP transistor is a mirror-image of an NPN transistor and is turned **ON** by a finger as shown in this animation:



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These animations are designed to help you "SEE" a circuit working. They represent a visual indication of how an **electronics engineer** sees a circuit in operation. **He sees every part of a circuit working and moving and when a fault develops, he can SEE WHY!**

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These animations only show half a cycle.
The other half-cycle turns the transistor OFF (referring to the **Regeneration** and **Feedback via a Transformer** animations). Turning the circuit **OFF** is complex and will be covered in a future chapter.

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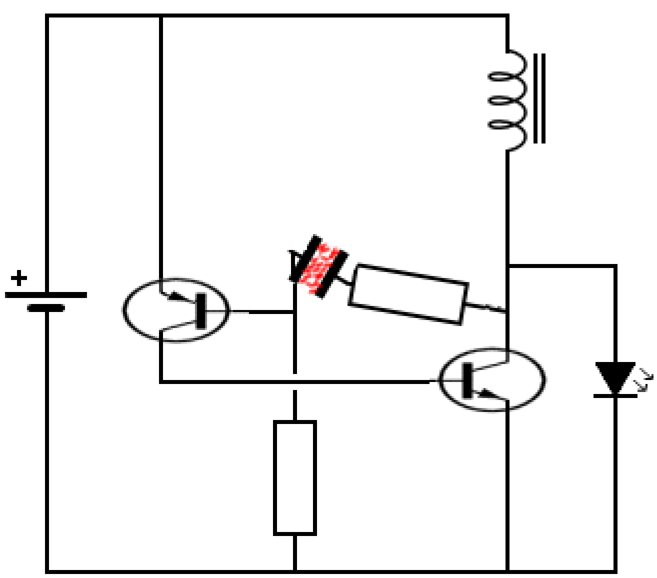
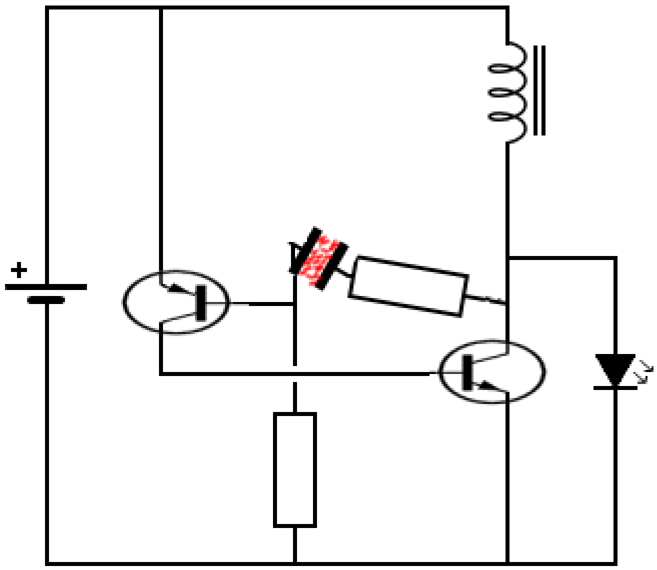
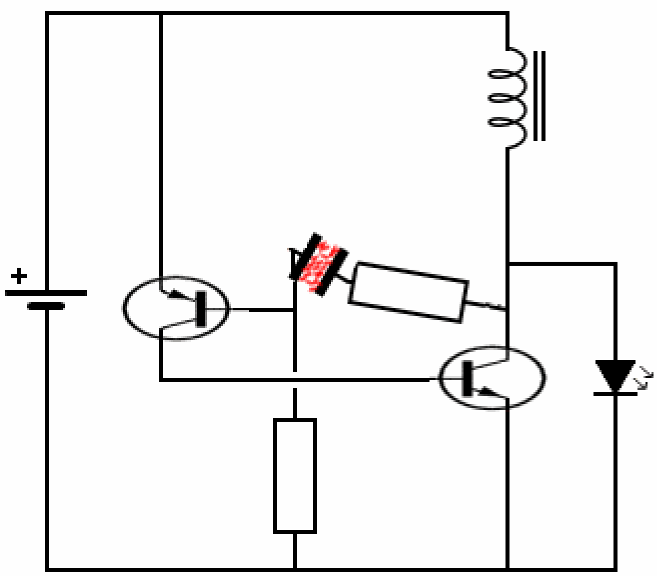
This animation shows many of the features we have covered.
It is very difficult showing an animation because some of the components are reacting to voltage-changes and some to current changes (the transistors).
That's why you need to study many different animations from different circuits to be able to generate a picture of how a circuit is working.
In this animation we have an inductor, a capacitor and two types of transistors.

HOW THE CIRCUIT WORKS:

The circuit turns ON via the 220k resistor and the voltage on the collector of the NPN transistor drops to nearly 0v. This action causes current to flow through the inductor and at the same time the 1n capacitor is brought towards the 0v rail and this turns ON the first transistor slightly harder. This action continues until the driver transistor cannot be turned on any more.
The 1n charges a little more and the current through the base lead reduces slightly. This action turns OFF the first transistor slightly and the driver transistor is turned OFF a slight amount.
The voltage on the 1n rises and very soon both transistors are fully turned OFF.
The magnetic flux in the core of the 1mH inductor collapses and produces a voltage in the opposite direction.
This voltage is added to the 1.5v rail voltage and the final voltage is high enough to illuminate the white LED (approx 3.6v).
This keeps both transistors OFF and when all the magnetic flux has been converted to energy to illuminate the LED, the voltage on the collector drops. This lowers the top plate of the capacitor and since the capacitor is slightly charged, the bottom plate drops to a voltage less than rail voltage. This action turns ON the first transistor to start the next cycle.







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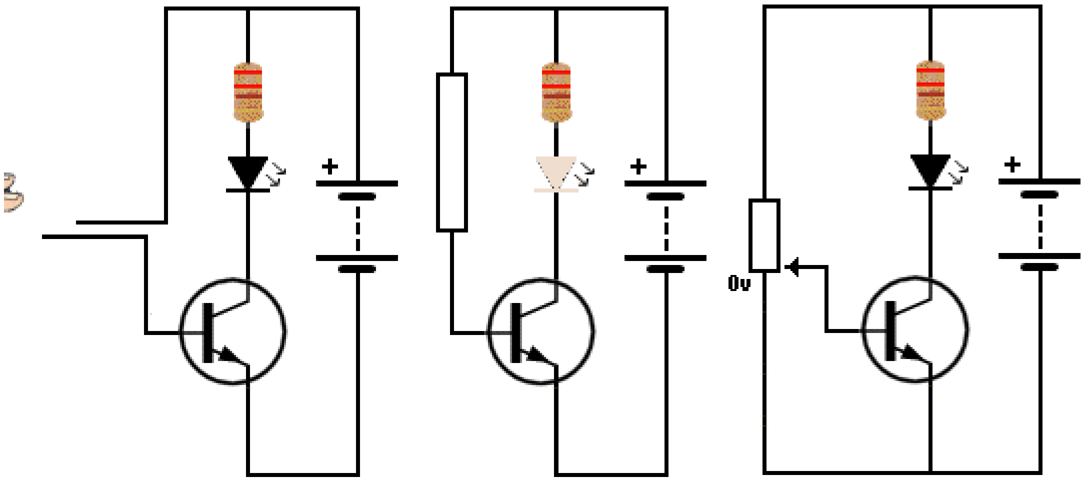
Turning **ON** a transistor is more complex than shown in the animations. A transistor is turned **ON** when the base sees a voltage higher than 0.6v and the voltage will also allow a **CURRENT** to be delivered. These two requirements are normally provided in a circuit and your finger pushing on two wires will provide the voltage and current.
Here is an animation of what your finger is doing:



Pressing hard on the two wires is the same as reducing the value of the base resistor or turning the potentiometer. The action allows more current to enter the base of the transistor. The transistor amplifies this current about 100 times and illuminates the LED.

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We have shown how to turn on a LED with a transistor.
A LED takes about 20mA and it' s easy to illuminate with a transistor because 20mA is a small current and any transistor will deliver this current.
But suppose we want to illuminate a 6v torch globe that takes about 500mA when fully illuminated.
Some transistors only allow about 100mA to flow through the collector-emitter junction and they will either get too hot or "burn-out" when 500mA is flowing.
You need a transistor that allows more than 500mA to flow.
The two transistors will will use are BC337 (BC338) and 2N2222A. These transistors will pass up to 800mA without being damaged.

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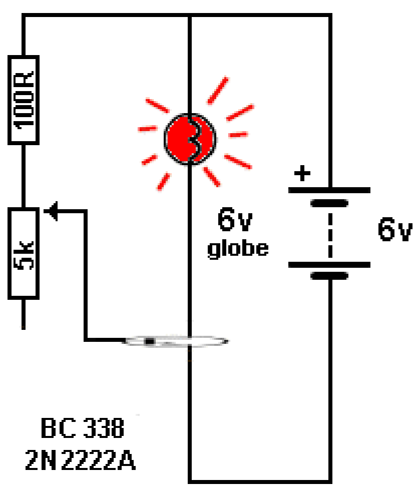

The BC 338 transistor handles the globe current

DIM A TORCH GLOBE

Connect the globe to the transistor and uses a 10k mini trim pot to adjust the base current. The 100R is called a "STOP RESISTOR" to prevent too much current flowing into the base and destroying the transistor. > Connect the circuit and turn the pot to zero ohms so that just the 100R is supplying current to the transistor. Feel the transistor.
Now turn the pot a small amount and keep feeling the transistor.
The lamp will be at about the same brightness but the transistor will get hotter. Move the pot a few more degrees and the transistor will get much hotter.
Keep turning the pot and the transistor will get much hotter when the globe is quite dull.
We will discuss the reason why it gets hot in a future lesson .

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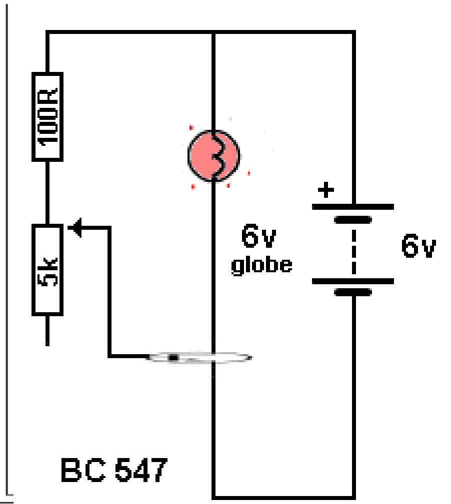
Connect a BC547 transistor to the circuit and turn the pot to zero ohms to get the lamp as bright as possible.
Feel the heat of the transistor.
It will be much hotter than the BC337 and the lamp will not be very bright.
The transistor cannot pass the required current. You are overloading the transistor and is will possibly burn out.
This transistor is not suitable for the application.



Do NOT try to reduce the brightness of the globe by connecting just the pot to the globe. The pot will "burn-out" very quickly. You must always include the transistor.
All the globe current cannot go through the pot as this will burn the track inside the pot.
The transistor allows only 1/100th of the globe current to pass through the pot.

A BC337 transistor has a larger amount of silicon in the junction(s) and that is why it will pass (handle) a larger current.

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A BC 547 will not handle the globe current.

1. The transistor is coolest when it is illuminating the globe with full brightness.
2. The transistor must be able to handle the globe current.

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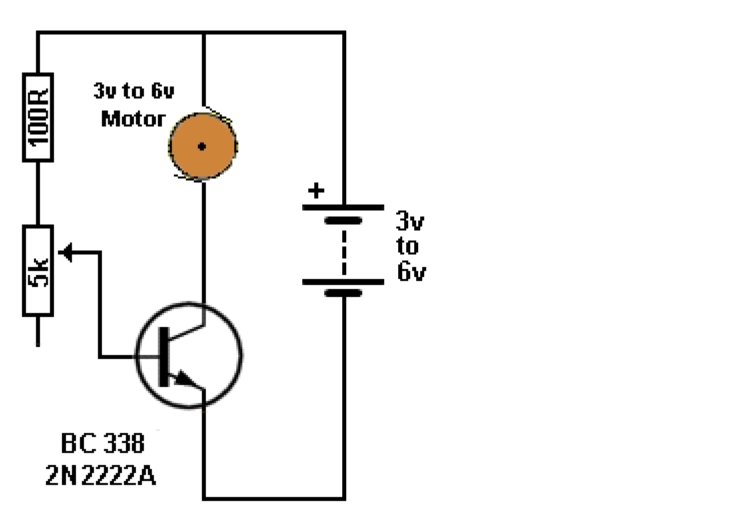

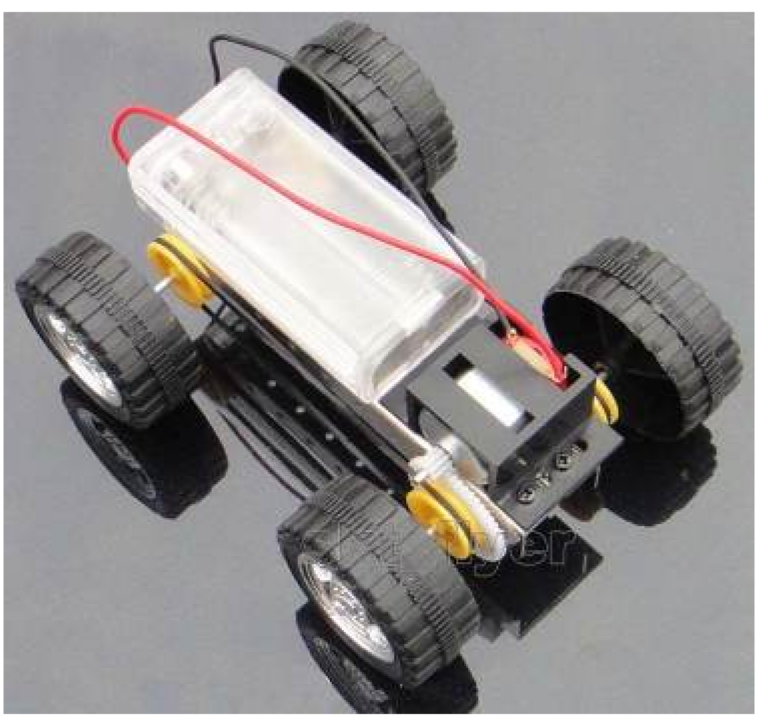

MOTOR SPEED CONTROL

The RPM (commonly called the "speed") of a motor can be varied by the circuit shown.
You will need a 3v to 6v motor and 4 wheels on a chassis. The car in the photo is available as a kit from eBay.
Add the circuit and use a mini trim pot to adjust the speed.

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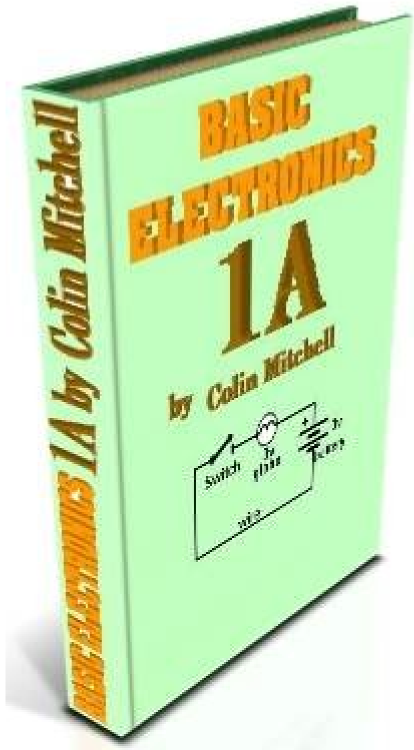
	TRANSISTOR TESTER - 22 Here is a



For any enquiries email Colin Mitchell

The Power Supply

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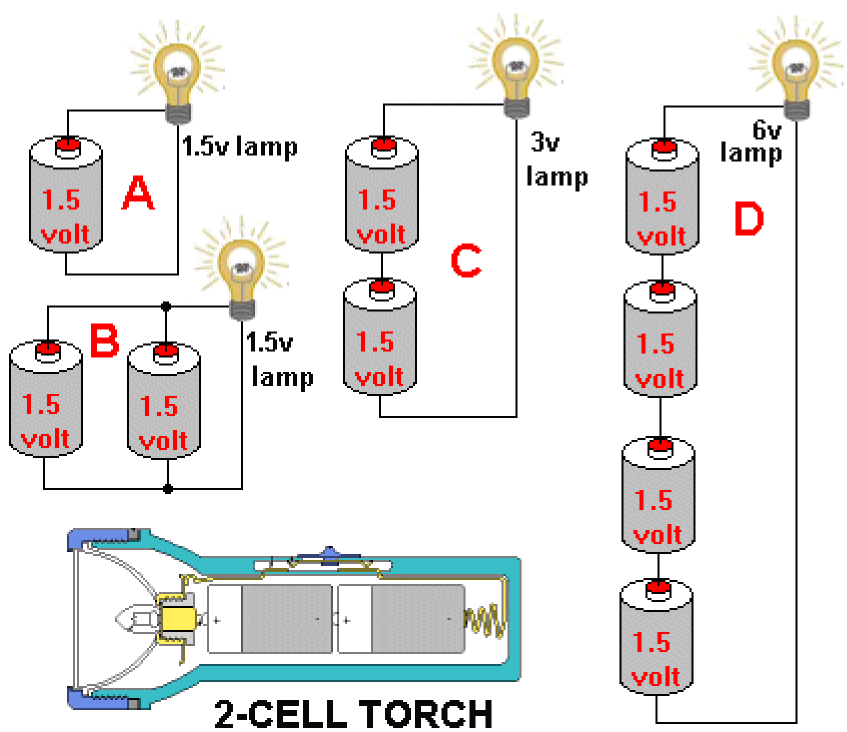
[Negative Rail](#)
[Parallel](#)

THE POWER SUPPLY

There are many different types of power supplies, including batteries, plug packs, switch-mode supplies and a basic transformer and bridge.
Most modern equipment is powered by a very compact power supply called a **SWITCH MODE POWER SUPPLY**. (**SMPS**)
It uses advanced technology and a chip to drive the circuitry at a very high frequency so the isolating transformer can be very small.
We will not be covering this technology.
However the simplest power supply consist of a transformer, one or more diodes and a large filter capacitor (electrolytic).
This is a basic **POWER SUPPLY** and we will cover it.
It will involve connecting to the **MAINS** and this is very dangerous.
But first we will cover the **BATTERY** as a **POWER SUPPLY**.

CELLS in PARALLEL AND SERIES



The diagrams show cells in **PARALLEL** and **SERIES**.
Diagram **A** shows a single 1.5v cell connected to a 1.5v globe.
Diagram **B** shows two 1.5v cells connected in PARALLEL to a 1.5v globe. 2 cells in parallel are just like one big cell.
Diagram **C** shows two 1.5v cells connected in SERIES to a 3v globe. When cells are connected in SERIES, you add the voltages of each cell.
Diagram **D** shows four 1.5v cells connected in SERIES to a 6v globe. The voltage of the globe must be the same as the voltage produced by the cells otherwise the globe will be too dull or it will "burn-out."
When two or more cells are connected in **SERIES** the result is called a **BATTERY**.

Fig 1. CELLS in PARALLEL AND SERIES

Fig 2. The CELLS in a 9v BATTERY

CELLS in a 9v BATTERY

There are 6 cells in a 9v battery. But the cells are very small and they don't hold much ENERGY.

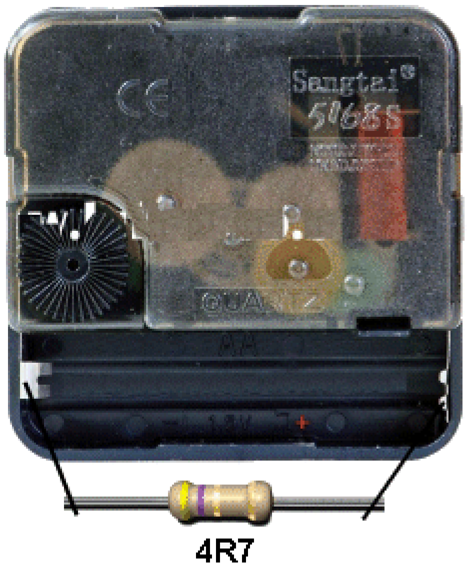
This means 2 things:
The battery cannot deliver a high current and it can only deliver a small (low) current for a short period of time.
The first two pictures are commonly called "dry cells" and the other two pictures are Alkaline cells.
Alkaline cells are more expensive but they can deliver 3 times more energy than a dry-cell.

HOW LONG WILL A BATTERY LAST?

When you buy a battery, it has already lost some of its energy via leakage inside the cells so it is impossible to work out how long it will last.
Secondly, the life of a battery depends on the current drawn from it.
It also depends on how long it is used for during each "session" and how much rest it gets.
It also depends on the temperature of the day and the "end-voltage" - this is the voltage of the "dead battery" and it is different for each piece of equipment.
It also depends on the quality of the chemicals used in the construction and the sealing of each cell to prevent internal leakage. There are so many variables.
The average **9v Carbon-Zn** will deliver **300mAHr**
The average **9v Alkaline** will deliver **500mAHr**

What is mAhr?
mA is milliamp. There are 1,000mA in 1 amp. mAHr is milliamp multiplied by hours.
A 9v Carbon-Zn battery will deliver 1mA for 300 hours.
A 9v Carbon-Zn battery will deliver 10mA for 30 hours.
A 9v Carbon-Zn battery will deliver 15mA for 20 hours. (If you take more than 15mA, the capacity of the battery will be less than 300mAHr).

But there is one major difference between the two types of 9v battery.
A new **9v Carbon-Zn** battery will deliver about 200mA for a very short period of time.
A new 9v Alkaline battery will deliver about 2 Amp (2,000mA) for a very short period of time.
That's why you can use a 9v alkaline battery in a Stun Gun. It takes over 1 amp to produce the 50,000 volt spark.
A **"AAA"** dry-cell has approx 600mAHr @ 30mA current
A **"AA"** dry-cell has approx 1,000mAHr @ 75mA current
A **"C"** dry-cell has approx 2.5AHr @ 150mA current



A **"D"** dry-cell has approx 5.5AHr @ 250mA current
Alkaline cells have approx 2 times more capacity and will perform about 5 times better at high current demand.
You can test rechargeable cells to determine if they still have full capacity by connecting them to the clock mechanism on the left. The 4R7 resistor will draw a considerable current and the clock will stop when the battery reaches 0.7v. Start the time a 12:00 and the hands will show the number of hours of operation.
This is a "comparison test" and by testing other cells you will be able to determine if any of the cells are faulty.

THE BATTERY as a POWER SUPPLY

A battery is an ideal POWER SUPPLY because it is CHEAP, it will deliver a fixed VOLTAGE and plenty of CURRENT when required.

There are many different types of batteries. Some are RECHARGEABLE, some are HIGH CURRENT and some are LOW COST.

To cover all the cells and sizes would take a book so we will limit our discussion to a few different types.
The simplest battery is made from AA or AAA cells.
Use the largest cells you can fit into your project. This will allow the project to operate for a long period of time. It will be the cheapest and most economical way to power a project and give the best performance.

BATTERY TERMS (Terminology)

A **BATTERY** is a good **POWER SUPPLY** because it will deliver a small or large **CURRENT** as required by the project.
A battery supplies **DC VOLTAGE** - the letters **DC** actually mean **Direct Current** and that's one of the unusual concepts of electronics.
As a battery is "used" the energy is removed by eating the zinc case and eventually we say the battery is **FLAT**. This means it is not suitable for the application because either the voltage is too low or it will not deliver the required current.
A 'Flat" battery can be detected by the volume (loudness) of an amplifier decreasing, the sound becoming distorted, or the globe in a torch becoming dull.
A battery gets "used up" and its **INTERNAL RESISTANCE INCREASES**.
This causes the output voltage to decrease and the current will also decrease.
To fix the problem, simply replace the dry cells or recharge the rechargeable cells.

The **CAPACITY** of a battery:
Capacity is the total amount of energy stored in a cell.
It is a combination of the voltage of the cell and the length of time a current can be delivered.
It is measured in **mW-hrs** or **W-hrs.** In other words it is volts x amps x hours.
Cells with a voltage of 3.6v have an advantage over cells with an output voltage of 1.5v because they have a 240% higher capacity for the same size.
Most cells have a rating in mAHr but when you compare a 1.5v cell with a 3.6v LITHIUM cell, the a 240% higher capacity is a bonus.
12v RECHARGEABLE batteries are measured in A-Hr - such 1.2AHr or 4Ahr.
Automobile batteries are measured in "cold-crank amps." This is a vague term like "I can do "20 push-ups in one minute." It doesn't tell you how big and strong I am. The cold-crank amps has a weak connection to the amp-Hr capacity of the battery and how well-made it is.
A battery that can deliver a **HIGH CURRENT** is said to have a **LOW INTERNAL IMPEDANCE**.

IMPEDANCE is another word for **RESISTANCE.** Resistance can be measured with an **OHM-METER** whereas IMPEDANCE will have the same numeric value but cannot be measured with an Ohm-meter. It has to be worked out via Ohm's Law.

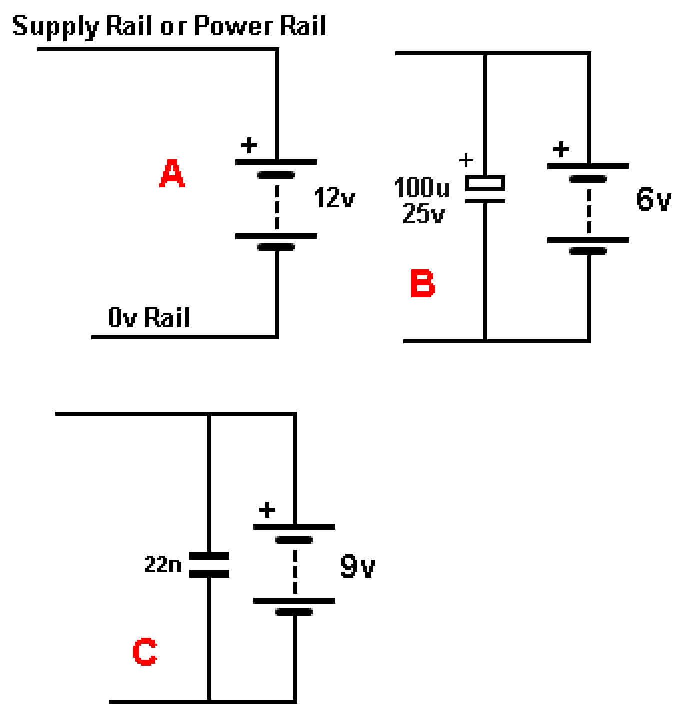


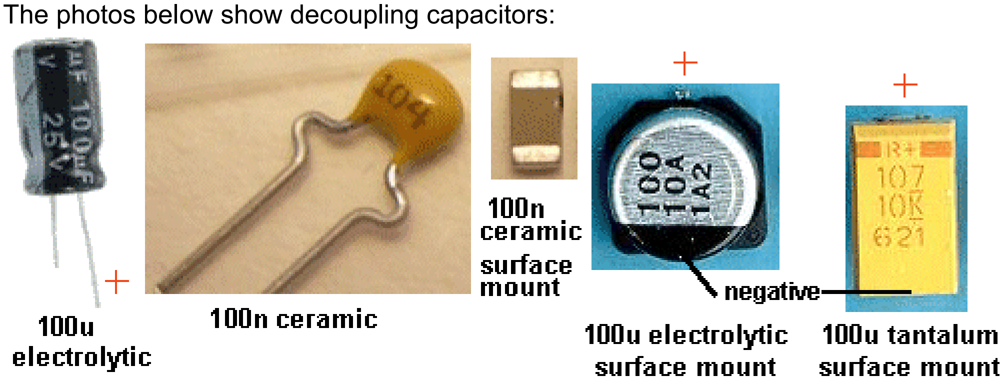
Fig 3. A BATTERY POWER SUPPLY

In simple terms, the electrolytic or capacitor improves the performance of the battery by "tightening up" the power rails (by reducing the impedance of the rails.)

A Battery **POWER SUPPLY** is shown in Fig **A**.
The top rail is called the **Supply Rail** and the lower rail is called the **0v rail**.
A battery supplies a DC voltage but as it gets "used" the voltage "dips" when a high current is needed.
This can create distortion in audio equipment and to solve this problem an electrolytic is placed across the rails.
The electrolytic is just like a miniature rechargeable battery and will supply current during the peaks of demand. See Fig **B**.
If the project is a high frequency circuit such as a transmitter (100MHz) the capacitor across the rails needs to be 22n as shown in Fig **C**.

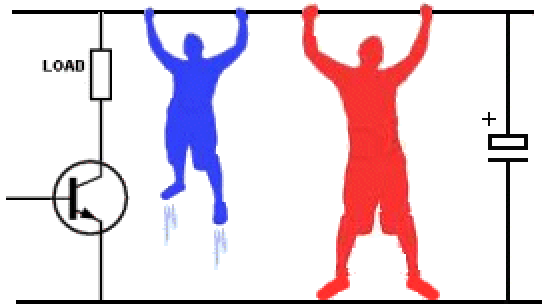
DECOUPLING CAPACITORS

The capacitor (or electrolytic) across the power rails stops the rail voltage dropping when a high current is required.
It "electrically" joins the **power rail** to the **0v rail** and this is very important in high frequency circuits such as transmitters, because the oscillator needs to "push against" the power rail to push the signal out the antenna.
A 22n across the battery improves the output considerably.
Quite often a 100n capacitor is added to each transistor stage (or IC) in a large project to prevent signals from one IC passing to another IC. In other words, the 100n ceramic capacitors prevent unwanted signals "coupling" one stage to another.
This is why the capacitors are called **DECOUPLING CAPACITORS**. They "decouple" or reduce the unwanted "spiky" signals.
When a capacitor is used to **join** one stage to another, it is called a **COUPLING CAPACITOR** and we need to separate the two terms.
The size of the capacitor depends on the frequency at which the circuit is operating and the current taken by the circuit.
The photos below show decoupling capacitors:



Surface-mount markings: 104 = 100n, 105 = 1u, 106 = 10u, 107 = 100u

Fig 4. DECOUPLING CAPACITORS



HOW THE CAPACITOR WORKS

The capacitor (or electrolytic) across the power rails rails works just like the two men in the drawing.
The first man is bouncing on the **Power Rail** just like the transistor is drawing a varying current and moving the rail up and down. The second man (the electrolytic) is holding the **Power Rail** steady.

Whenever you get a fault in project such as distortion, or LEDs not blinking at the right time or "funny effects," the first thing you do is add an electrolytic across the power rails.
That's because the impedance of the battery or power supply might be letting pulses from one section of the circuit get into another section and upset the operation. These pulses are short, sharp and very hard to detect but an electrolytic will solve the problem.
When a battery gets "old" the supply rail gets "very floppy" and that's when a lot of problems start to show.
The reason is the impedance (the resistance) of the battery starts to increase and the **Supply Rail** is not "tied" to the **0v rail**. That's what the electrolytic does. It effectively "ties" the **Power Rail** to the **0v rail**. This fact has never been mentioned before in any text book. It's most important when you start to work with high-frequency circuits as the power rail must be kept "rigid" and the only way to do this is to place a capacitor between the rails.

THE MAINS

For a project needing a long-term **POWER SUPPLY** or a **HIGH CURRENT**, the energy will come from the "**MAINS.**" You don't have buy batteries and the overall cost is much less.
The "**MAINS**" is a voltage of either 120v AC or 240v AC.
It is rising and falling at a rate of 50 or 60 times per second and this is called the frequency.
Frequency is measured in Hertz, with 50Hz or 60Hz being the frequency of the Mains.
Since the voltage is rising and falling we call it ALTERNATING and because the CURRENT is the part of the Mains that provides all the work (heat) it was the most important part of the MAINS.
That's why they called the Mains, **AC (ALTERNATING CURRENT)**.
The Mains is a very dangerous voltage to deal with as the 120v AC is really a voltage that rises to 180v and then drops to minus 180v at the rate of 60 times per second.
The 240v is really a voltage 345v and then a voltage of minus 345v, rising and falling at a rate of 50 times per second.
Your body can only handle 60v to 80v and anything above that can cause instant death.
That's why building a power supply and having mains voltages present on your work desk requires extreme caution.
I have not been electrified or received a shock in any of my past 50 years because I am very careful and follow this simple rule:

Only touch any part of the circuit with one hand and do not let any other part of your body or feet touch any pipes or bare floor.
Electricity must pass **through** your body to earth or a pipe or another wire to produce "electrocution."

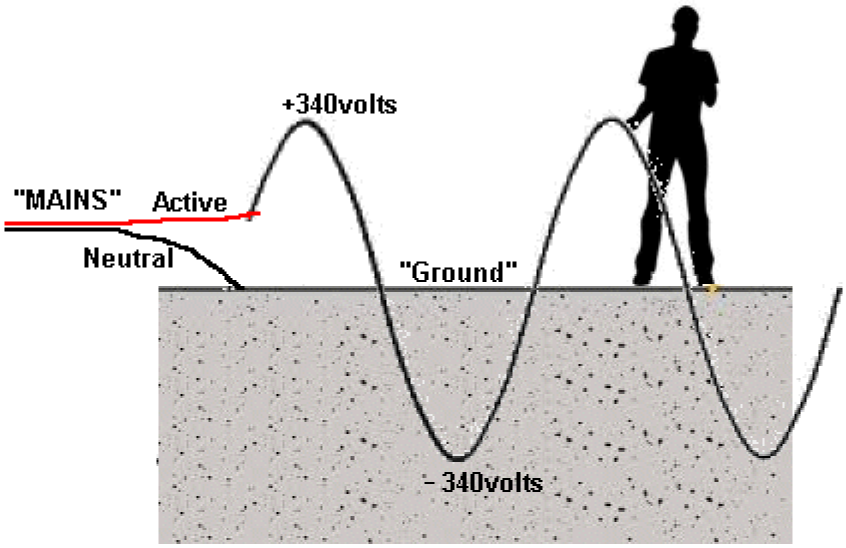


Fig 5. The "Mains" WAVEFORM

The "**MAINS**" is dangerous because the voltage is much higher than stated on any appliance.
It is actually 180v or 345v for the 240v mains.
The ACTIVE lead rises 340v then falls 340v below "ground" 50 times per second and this will produce a CURRENT FLOW through your body that will kill you very quickly.

The EARTH

All "Mains" sockets consist of an **ACTIVE**, **NEUTRAL** and **EARTH**. This is called a 3-pin system with a 3-pin plug.
The most important connection is the EARTH because it protects you from getting a "shock."
It is important to understand the Active and Neutral carry the "electricity" (called the CURRENT) and the earth is GENERATED by driving a spike into the ground at the front of the premises.
The Active and Neutral enter a property via either overhead or underground via two separate wires or a screened wire with the ACTIVE in the middle and the NEUTRAL wound around the outside.
These two wires go back to a transformer on a lamp-post or in a sub-station where the 240v is produced by a transformer. As we know, the secondary of a transformer is not connected to any other wiring so one of the leads is connected to a wire that runs down the lamp-post to a metal rod or pole of spike driven into the ground.
This wire becomes the NEUTRAL as it will not have any voltage on it.
The other wire is called the ACTIVE and these two wires go to each home.
At the meter-box, these two wires are connected to each outlet as ACTIVE and NEUTRAL.
But suppose the wire going to the rod (called a spike) at the lamp-post gets broken.
The two wires will now be "floating" and if you touch the Neutral, you will get a tingle.
For instance, if you have a toaster and the heating element is connected to Active and Neutral, and the metal frame is not connected to anything, you will get a slight tingle if the element has a slight leakage to the frame.
This is because all the voltages are "up in the air."
Now we introduce a SAFETY wire. It is called EARTH.
At the front of the house we hammer a long spike into the ground and connect a green lead.
We take this green lead to the earth pin of all the outlets.
This wire is connected to the frame of all appliances.
Now, it does not matter if the Active and Neutral are "up in the air" because the frame of the toaster is SAFE to touch.
But the Active and Neutral are NOT UP IN THE AIR. The neural is connected to the ground via a spike at the lamp-post.
The earth spike at your house is just like a shield or screening around the other two wires so you cannot touch either wire. You must not be able to touch either wire because someone may connect the wires incorrectly on an extension-lead and the black wire will give you a shock.

X

Fig 6. A 12v WALL WART (Plug Pack)

A BASIC POWER SUPPLY

A **Basic Power Supply** consists of a transformer, rectifier and storage capacitor.
A transformer involves connecting two leads to the mains and these items can now be purchased as a sealed unit as a PLUG PACK or WALL WART, so you cannot touch the mains wires.
A Wall Wart is "so-called" because it takes over the wall socket so nothing can be fitted into the adjacent socket!!
It is suggested that a fully approved PLUG PACK be purchased to power any project in this course and use the following notes as instructional material.

A BASIC POWER SUPPLY - Part 2

The circuit for a Basic Power Supply is shown in **Fig 7 and 10**.
The mains can be 120v or 240v and the transformer used in the project is designed for the exact voltage. You cannot use a 120v transformer on 240v or 240v transformer on 120v.
The 120v /240v is called the MAINS and it rises and falls at either 60 or 50 times per second.
This frequency is called Hertz (Hz) and it produces flux (called MAGNET FLUX) in the core of the transformer.
The core is called a **MAGNETIC PATH** and the number of turns on the primary winding produces the maximum magnetic flux for the type of material used in the core.
The turns are then counted and this provides the data: TURNS PER VOLT.
If the answer is 6 turns per volt, we can wind another coil next to the PRIMARY WINDING and each 6 turns will produce 1v in the SECONDARY WINDING.
The primary winding takes up half the bobbin and the secondary winding takes up the other half.
If only a few turns are needed for the secondary, a large gauge of wire can be used.
The size of wire will give us the SECONDARY CURRENT, taking into account the heating of the transformer.
This produces 4 wires and the primary winding is separated from the secondary by a sheet of plastic.
When the primary is connected to the mains, the secondary is not PHYSICALLY connected to the mains and can be touched without getting electrocuted. It is MAGNETICALLY CONNECTED.
The transformer provides a SAFE voltage and a current (from the secondary winding) that can be used to power an electronic project.
Winding a transformer must only be done by a professional as the winding wire must not be scratched or allowed to touch the core of the transformer. The insulation between the windings must be certified and able to resist a high temperature. It must also be sealed to prevent the windings vibrating by dipping in resin and baking in an oven to set the resin.
This type of transformer can be bought as a PUG PACK or WALL WART where the primary winding is connected to pins and thus the mains is not exposed - and CANNOT BE TOUCHED.
The next component needed in a POWER SUPPLY is a rectifier.
This is a diode or set of diodes.
We have seen a diode can be used in a circuit to allow current to flow and when the battery is fitted around the other way, no current flows.
That's how it works as a **RECTIFIER**.
The mains is just like a voltage being delivered to the transformer and it starts a zero volts.
The voltage increases to a maximum then decreases to zero.
We talk about one of the wires as being neutral and equal to zero volts at all times and the other wire increasing and decreasing. This wire is called the ACTIVE.
The active wire then becomes negative and its voltage falls to as much as minus 180v or 345v. It then becomes less negative and finally reduces to zero. This is shown above with the waveform and image of a man and "ground."
A diode placed on the ACTIVE wire will allow voltage and current to flow though the diode when the voltage is "above ground" and no current (or voltage) will flow though the diode when the waveform is below ground.
This is the principle of **RECTIFICATION**.
It takes an AC voltage (a waveform) and only allows the top portion to pass through a diode.
If a diode is placed on the same waveform, in the reverse direction, only the negative portion of the waveform will be processed.

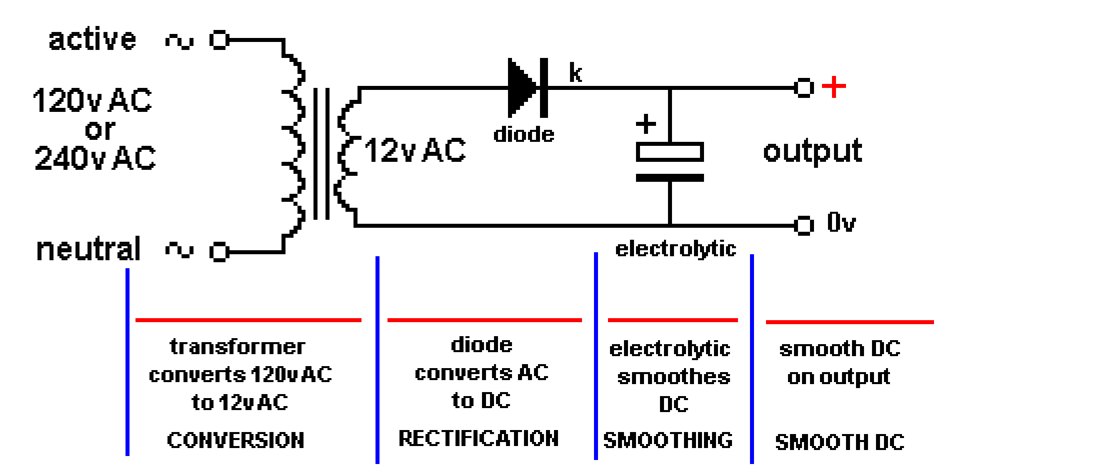
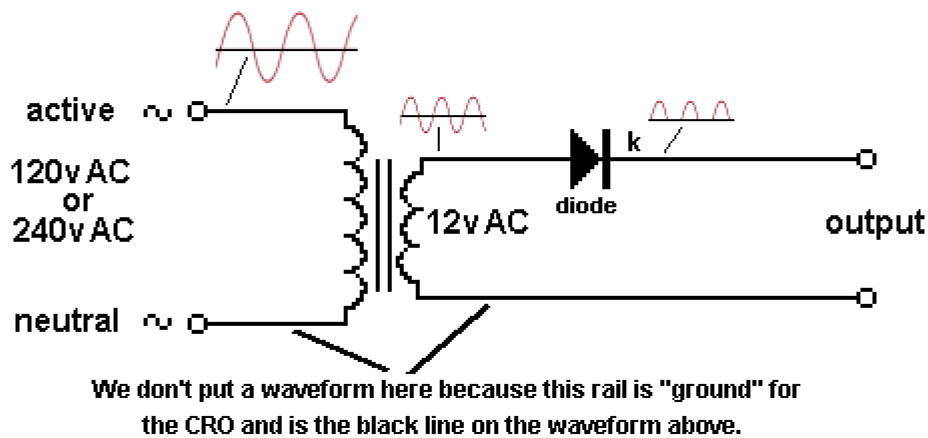


Fig 7. The MAINS POWER SUPPLY



When **one diode** is used on the secondary of a transformer, the circuit is called **HALF-WAVE RECTIFICATION**.
It is called **Half Wave** because only the positive of the mains (the "rising" part of the wave - the part **above** the black line) is passed to the output of the circuit.
This is a very wasteful circuit as only half the energy is used and it also heats-up the transformer because the unused portion of the waveform leaves flux in the magnetic circuit and this flux upsets the flux generated by the next portion of the cycle.
The diagram above shows a single diode and the output it produces. The output is called **UNFILTERED DC** and is not suitable for any electronic project as it will produce buzz, hum and faulty operation of a project. It is only suitable for charging a battery.

Fig 8. HALF-WAVE RECTIFICATION

By adding more diodes we can pass both the positive and negative portions of the secondary to our circuit and get a waveforms as shown in the diagram below.
This waveform cannot be used in any electronic equipment as it will produce a lot of background "hum."
In the next frame we will show how to improve the waveform.
The 4 diodes in the rectifier are called a **BRIDGE**.
The animation below shows how two diodes pass the positive waveform to the output and then the other two diodes pass the negative portion of the waveform.
We have removed the two diodes that are not active during each portion of the cycle to show how the other two diodes work.

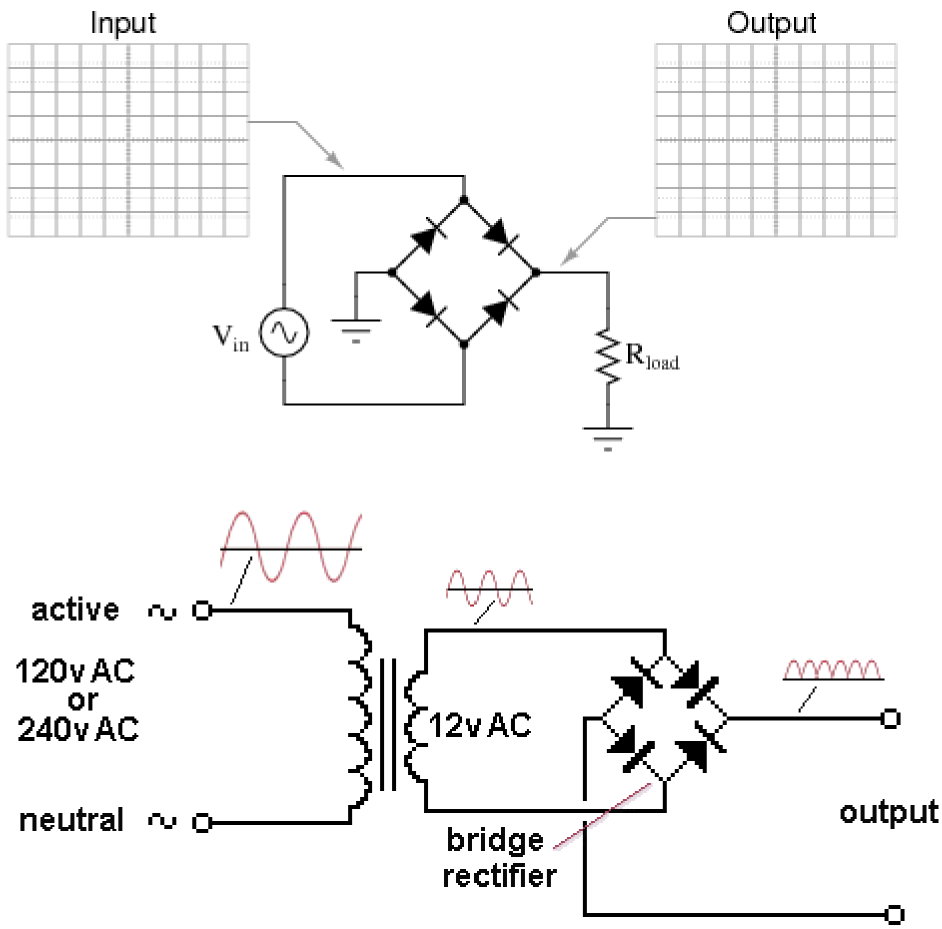
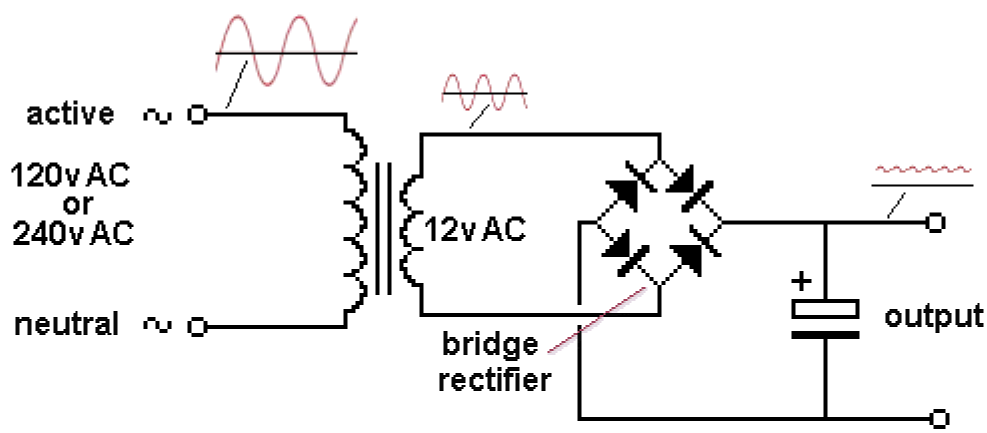


Fig 9. FULL-WAVE RECTIFICATION



The output needs to be **FILTERED** or **SMOOTHED** so the voltage can be connected to a piece of equipment.
The filtering is done with an electrolytic.
An electrolytic is like a rechargeable battery.
It gets charged when the voltage is high and delivers some of its energy when the voltage is low.
The result is a much smoother output.
The circuit above is inside a **PLUG PACK** (**WALL WART**)
The normal value for the filtering electrolytic is 1,000u for up to 1Amp supply.
We are not going into any mathematics to calculate this, however the formula is:

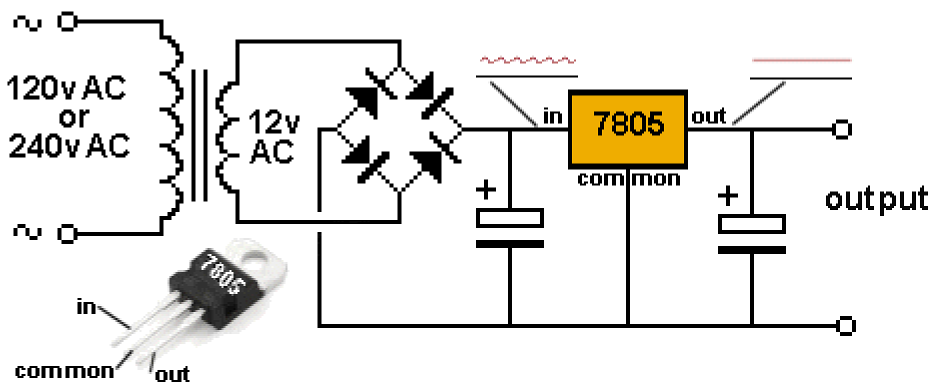
$$V_{\rm PP} = \frac{I}{2fC}$$

where Vpp is the ripple voltage produced after a bridge rectifier when current **I** flows (1amp) and f is the frequency (100Hz or 120Hz) and C is 0.001Farad (1,000u). **Answer = 5v**.
Any voltage above 100mV is noticeable in an amplifier and that's why a plug pack is not suitable for powering an amplifier. You need **additional** filtering in the form of a **regulator**.

Fig 10. FILTERING THE OUTPUT

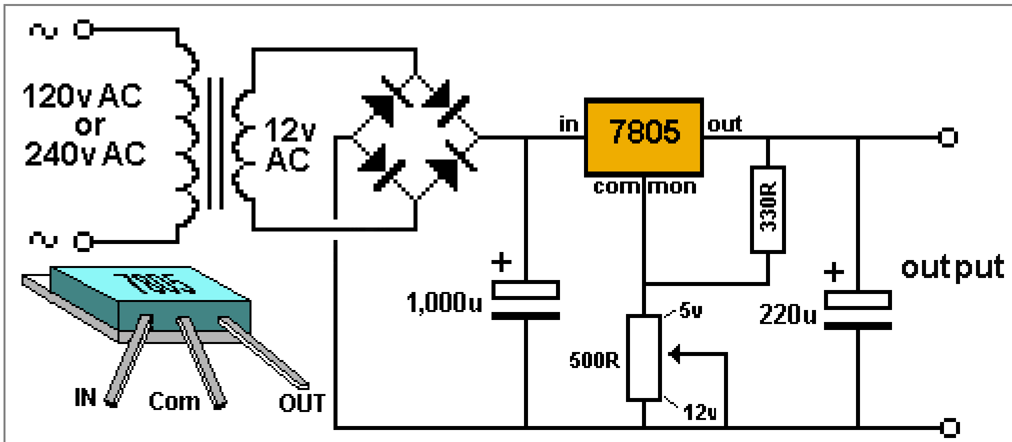
IMPROVING THE OUTPUT

Both the voltage and the ripple of the Power Supply above is not very good.
It is not good enough for modern equipment.
Most transformers produce a voltage higher than shown on the label and it can be as much as 5v too high.
In addition, the output has a ripple (as high as 5v p-p when drawing 1 amp) and this is noticeable in an amplifier.
This means the output can he higher than required (as some plug packs are 5v higher than the specified voltage of say 12v) and it can be "noisy" (the ripple increases when the current-demand is increased).
These two problems can be fixed with a **REGULATOR**.
This is a chip containing many transistors and components that electronically remove the ripple and produces a steady output voltage. (Steady means: FIXED and very low ripple).
These regulators are commonly called **3-TERMINAL REGULATORS** and look like a power transistor (also called **LINEAR REGULATORS**).



3-Terminal Regulators come in a range of fixed voltages and most are capable of handling 1 amp, provided they are correctly heatsinked so they do not get so hot you cannot touch them.
A 3-terminal regulator will reduce the ripple by about 1,000 times. In other words, a 5V ripple on the input will become 5mV on the output.
The electrolytic before the regulator removes most of the ripple from the rectifier and it should be about 1,000u for each 1 amp needed in the output. The electrolytic after the regulator prevents the regulator oscillating. It should be about 10u. A 100n can also be added before and after the regulator to prevent it oscillating.
Adjustable Regulators (such as **LM 317**) can be adjusted from 1.2v to about 35v and will deliver 1.5Amp. See Fig 14.

Fig 11. ADDING A 3-TERMINAL REGULATOR



The voltage of a 3-terminal regulator can be increased by putting a voltage-divider on the **COMMON** terminal. This increases the voltage on the common terminal and the output of the regulator is 5v higher than this value (if the regulator is a 5v component).

If the regulator is a 12v device, the output is 12v higher than the common terminal. This is called "**JACKING-UP**" a 3-TERMINAL REGULATOR.
7805 devices are 1 amp. 78M05 devices are 500mA !! Be careful !!!! They are really "failed" one-amp devices!!
The 78xx range of regulators are called **POSITIVE REGULATORS**
79xx are **NEGATIVE REGULATORS** - they have a different pin-out, so be careful.

Fig 12. "JACKING-UP" A 3-TERMINAL REGULATOR

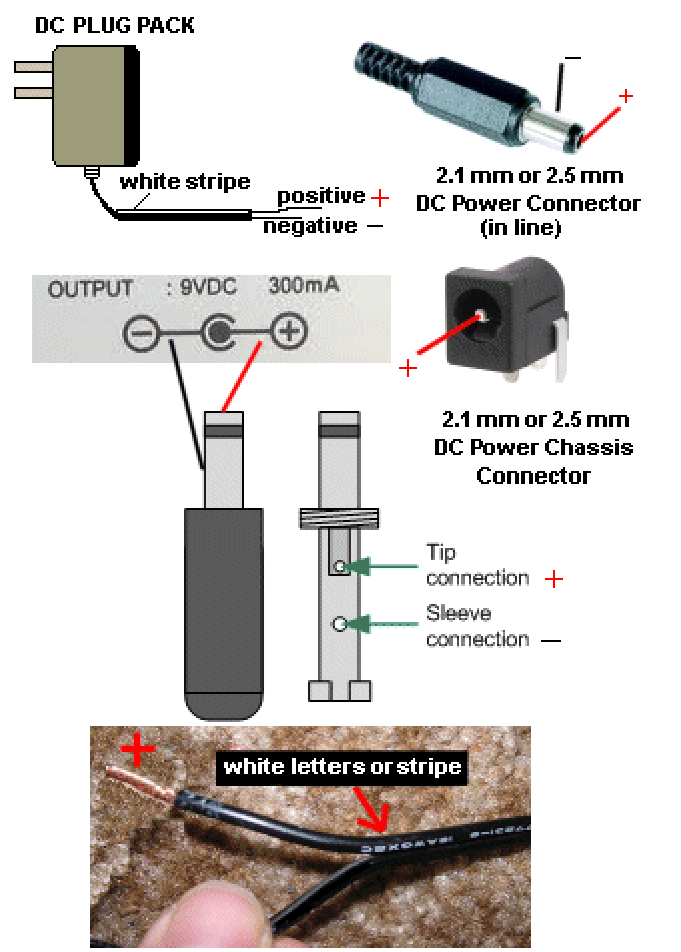


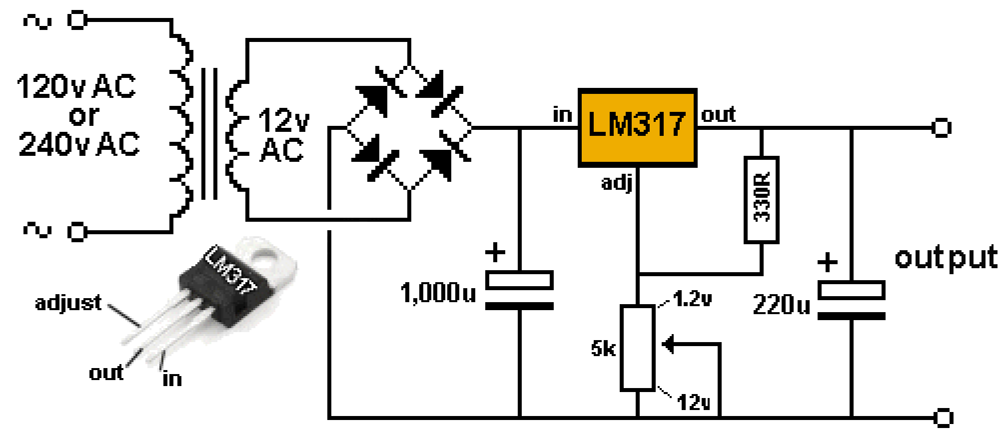
Fig 13. PLUG PACK POWER SUPPLY

PLUG PACK POWER SUPPLY

The simplest power supply is a **PLUG PACK** (WALL WART).
See **Fig 10** above for the circuit inside a Plug Pack.
It is **sealed** and safe and low-cost.
They are available in a wide range of voltages, current-ratings (300mA, 500mA and 1 amp) and some are AC output.
Most Plug Packs are **DC** and some are switchable from 4.5v DC to 12v DC.
Some have bare wires and some have a 2.1mm or 2.5mm "in-line" Power Connector with the TIP POSITIVE.
Some have a removable plug to make the TIP NEGATIVE.
The white stripe on the lead indicates the positive wire.

PLUG PACK POWER SUPPLY

DC Plug Packs contain a transformer, bridge rectifier and an electrolytic. The circuit for this is shown in **Fig 10** above.
This type of Power Supply is called **UNREGULATED**. This means the output voltage is not fixed and will normally be 3v to 6v HIGHER than the voltage stated on the case.
The reason for this is as follows:
The windings of the transformer have a small resistance and when it supplies a CURRENT to the device you are powering, the voltage drops a small amount.
To allow for this voltage-drop, extra turns are added to the secondary so the output voltage is 3v-6v HIGHER than stated on the label and when the FULL CURRENT is drawn, the voltage drops to the specified value.
The voltage is also higher so that the ripple (as high as 5v) will be "on top of" the 12v so the output will be a genuine 12v with some ripple "on top of" the voltage.
This is one of the problems with a Plug Pack and is called REGULATION.
Plug Packs have very poor **VOLTAGE REGULATION**.
Poor **Voltage Regulation** means the voltage starts at say 17v and drops to 12v when a load is applied.
A **Switch-Mode Power Supply** does not have this problem. The output is regulated and the voltage is FIXED over the range 1mA to more than 1 Amp.



Adjustable 3-terminal regulators are available and they can be adjusted from 1.2v to about 37v.
These regulators have a current-capability of 1.5 amp, providing they are heatsinked and the temperature of the device does not rise above 105°C.
LM317T and LM317 are identical. The plastic package is slightly different in shape.

Fig 14. ADJUSTABLE 3-TERMINAL REGULATOR

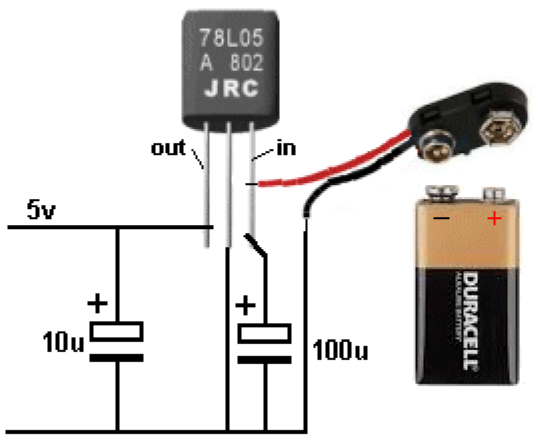


Fig 15. 100mA 5v POWER SUPPLY

When using a regulator, there are two things you have to remember.
The regulator needs about 3v to 4v across it to drive the circuitry inside it and it takes 3ma to 10mA. This means the battery voltage needs to be about 6v higher than the output of the regulator so the battery voltage can fall and the circuit will still work perfectly. A 9v battery will only just be ok.

A 100mA regulator can be used to produce a 5v regulated power supply from a 9v battery.

The 78L05 takes 3mA to 5mA to operate the internal circuitry and the minimum input voltage is 7v.
A 9v alkaline cell will supply 25mA (plus 5mA for the regulator) to a load for 15 hours. At this point the voltage of the battery will reach 7v and the regulator will "fall out of regulation." The 5v rail will drop to 4.75v, 4.5v etc. However the circuit will deliver up to 100mA for short periods of time with a fresh battery.
A switch is needed on the battery as the regulator takes 3mA to 5mA when it is working and you cannot leave it connected as the battery will eventually go flat.
There are some regulators that drop only about 1v across them. They are called LOW-DROPOUT. You need to look up their part number.

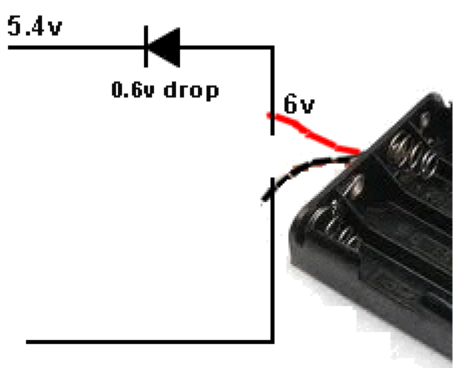
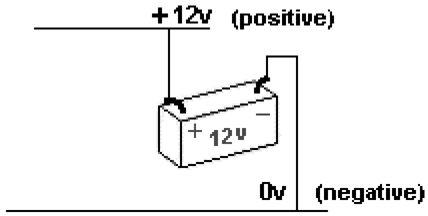
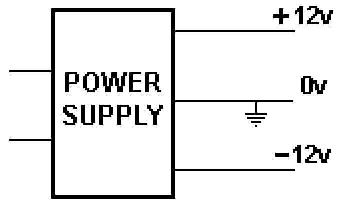


Fig 15a. Another 5v POWER SUPPLY

Many chips and microcontrollers require a 5v supply and it must not go higher than 5.5v.
By using four 1.5v cells and a power diode in the positive rail, a 5.4v supply can be created.
The circuit relies on the fact that the power diode will drop 0.6v to produce 5.4v for the project.
This is a very handy feature for battery-operated equipment and the battery-pack must not be higher than 6v.
(Any silicon diode will drop 0.6v. A Schottky diode will drop 0.3v).





Sometimes you will see a circuit as shown in the **first diagram** with 12v or +12v on the top rail and 0v or a negative sign or the word "negative" on the bottom rail. In **this case** the word negative means earth or "chassis of a car" and we commonly refer to this as "negative earth" or "negative chassis" and we really mean "0v chassis."
In the **second diagram**, the output from a power supply has a positive 12 volts and a negative 12v with the 0v rail in the middle. In **this case** the negative 12v rail is twelve volts BELOW the earth rail and that's why we call it the NEGATIVE RAIL.
This means that when you see "Negative Rail," you need to work out if it means the negative terminal of a battery (as in the first case - meaning 0v or earth) or if the voltage is below zero volts (as in the second case).

VOLTAGE AND CURRENT

A power supply will deliver two things.
It will deliver a VOLTAGE and it will deliver a CURRENT.
Voltage is the tingle you get on your tongue when you touch a 9v battery.
Current is the heat you feel when you put a resistor across the terminals of a 9v battery.
An **OPEN CIRCUIT** is a switch that is not pressed.
A **CLOSED CIRCUIT** is a switch that is pressed and the normal current flows.
A **SHORT CIRCUIT** is a fault in a circuit and **EXCESS CURRENT** flows. One or more components may get very hot or "burn out" or the plastic on the wiring may "start to smoke."
A **SHORT CIRCUIT** is generally two wires touching or components touching each other and the voltage flows through components that have a very low resistance. Because the resistance is very LOW, a **LARGE CURRENT** flows.
Some batteries (such as alkaline cells), rechargeable batteries (and cells) and some power supplies can deliver a **HIGH CURRENT** when components touch each other and this can destroy them. When you are experimenting and designing a project, it is good idea to use DRY CELLS as they can only deliver a small current if a fault develops.

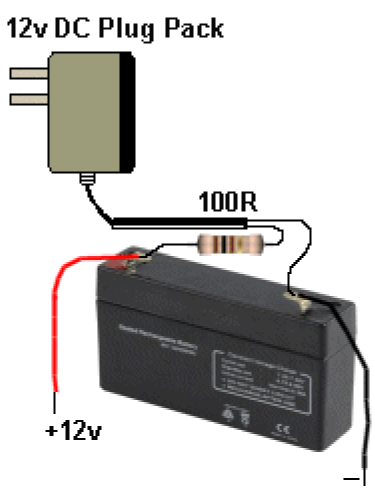


Fig 16. BENCH POWER SUPPLY

This Power Supply will deliver a **VERY HIGH CURRENT** so be careful to avoid any **SHORT CIRCUITS**.
You can use 2, 3, 4 or more rechargeable cells in place of the 12v battery.

BENCH POWER SUPPLY

A power supply on your work-bench is called a **BENCH SUPPLY** and it can be anything from a set of cells to a very expensive adjustable POWER SUPPLY.
We mentioned above the problem with a Power Supply that can deliver a HIGH CURRENT.
Your project can "go up in smoke" if a short-circuit is present.
That's why it is best to use cheap dry cells and avoid the possibility of destroying anything.
However if you want a cheap **Power Supply** capable of delivering a HIGH CURRENT, here is a low-cost **BENCH POWER SUPPLY**.
It uses a 1.2AHr rechargeable battery and a 12v DC plug-pack to keep it charged. All you need is a 100 ohm 0.5watt resistor in the positive lead to keep the charging current below 50mA and the battery will never get overcharged and it will be ready for all occasions.

Now that you have learnt about the POWER SUPPLY and possibly built one for your work-

bench, you will want to know how to use it.

VOLTS AND AMPS

The two values (called UNITS) we need to measure are **VOLTS** and **AMPS**.
VOLTS are normally measured in values from 1volt to many thousands of volts but when the voltage is less than 1v, we use the term **millivolt**. 1,000millivolt = 1volt
We can also write: 2,500millivolt = 2.5v or 2,500mV = 2v5 These are the same reading.

We also need to measure **CURRENT**. Current is measured in **AMPS**. For most electronic work we measure the sub-multiple: "milliamp." 1,000 milliamp = 1 amp.
We can also write 2,500mA = 2.5A

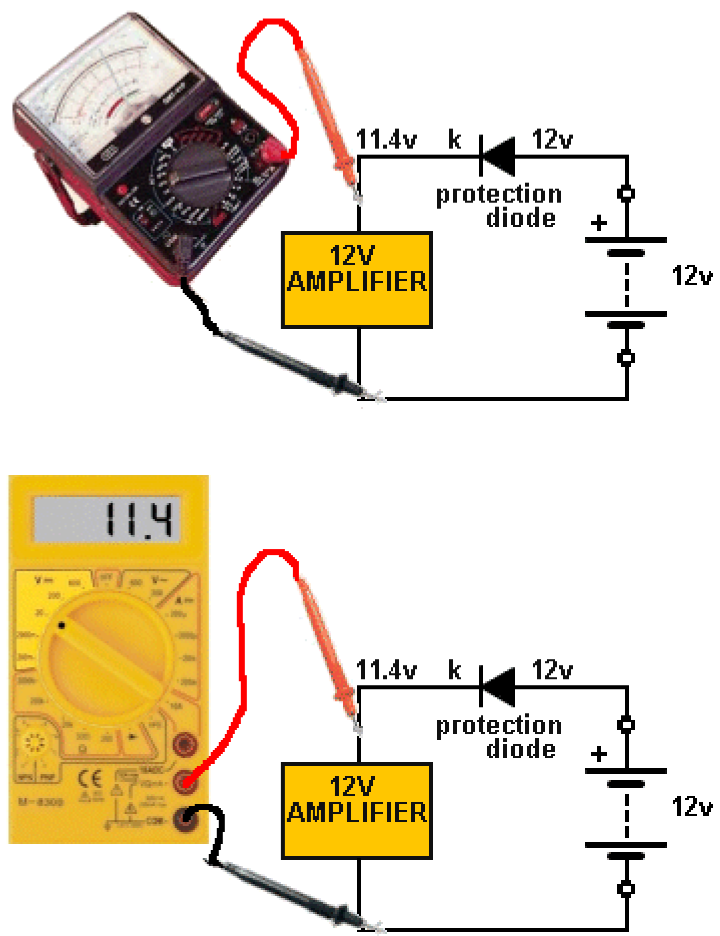
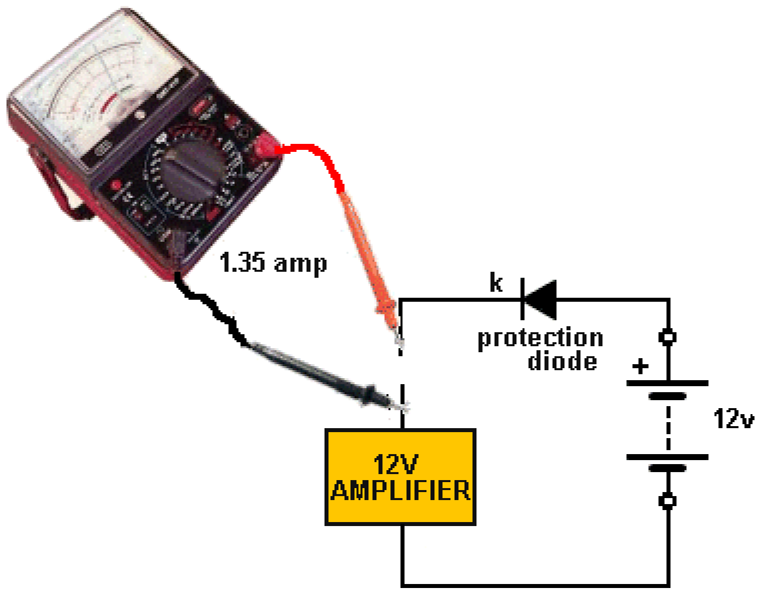


Fig 17. Measuring Voltage

MEASURING VOLTAGE

To measure **VOLTAGE** you need a **VOLTMETER**.
A Voltmeter is available on all **MULTIMETERS**.
It is one of the **RANGES**.
It is identified by the letter "**V**" or "**mV**"
There are two types of **MULTIMETER**:
ANALOGUE and **DIGITAL**.
Analogue Multimeters have a needle and must be connected around the correct way to make the needle swing "up-scale."
The red probe connects to the positive side of the component you are measuring and the black probe connects to the negative side.

Digital Multimeters have a screen and can be connected either way around. The screen will produce "-" if the probes are connected around the wrong way.



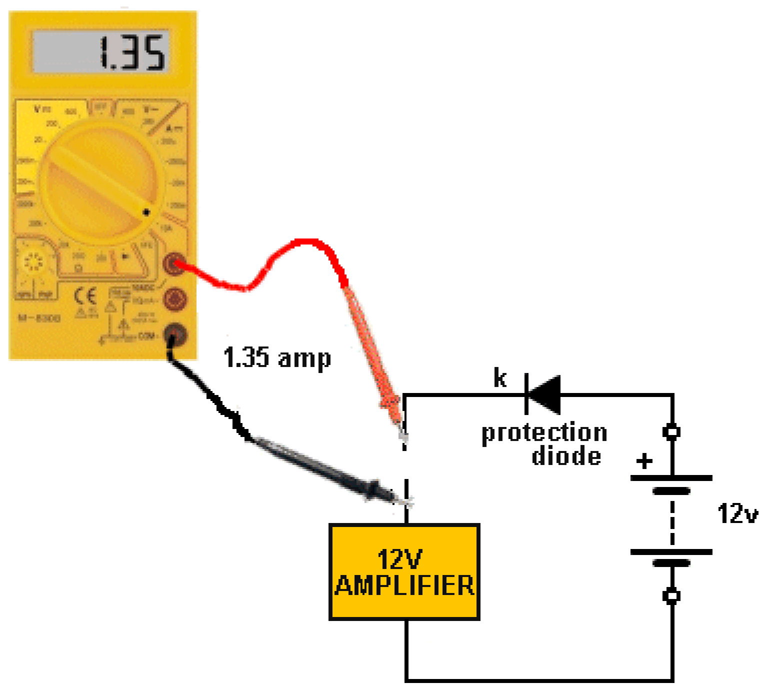


Fig 18. Measuring Current

MEASURING CURRENT

To measure **CURRENT** you need an **AMMETER**. An Ammeter is available on all **MULTIMETERS**. It is one of the **RANGES** identified by the letter "**A**" or "**mA**"
To measure 1 amp or more you need to select the 10AMP range.
Current is measured by "breaking into the circuit" and inserting the probes so the positive probe (red probe) is closest to the positive of the battery. The black probe is connected to the other side of the "cut."
Do not put the probes directly across the battery as this will cause a large current to flow through the multimeter and either "blow the fuse" in the multimeter or overheat the leads.

A multimeter on a CURRENT SCALE is classified as a "LOW RESISTANCE DEVICE" (or piece of test equipment) and acts just like a "**SHORT CIRCUIT**." That's why it can only be placed in series. If placed across a battery, it will act like a **SHORT-CIRCUIT** and be **DAMAGED**.

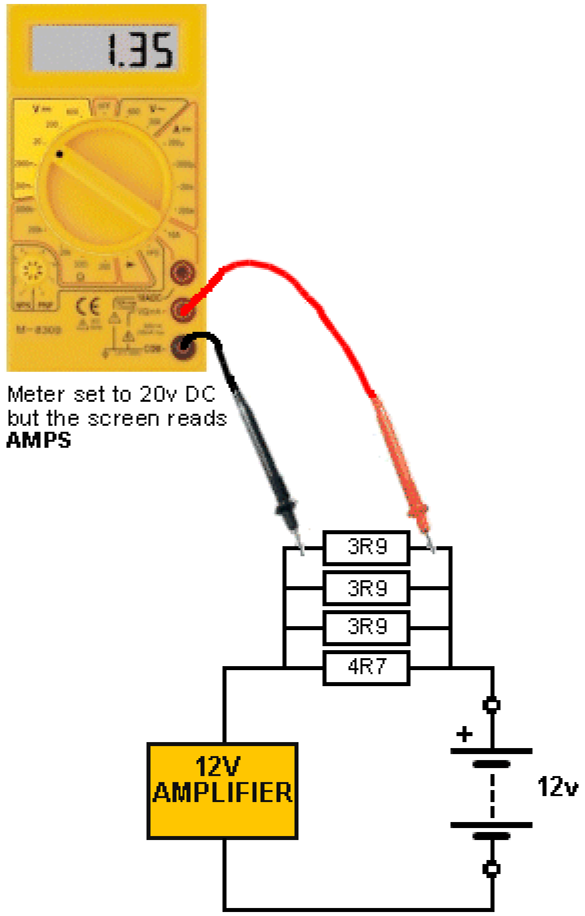


Fig 19. Making an AMMETER

Suppose your multimeter only has a current reading to 500mA and you need 1amp.
You can make your own **0 - 1amp** scale by connecting 4 resistors in parallel.
Use 3 x 3R9 and 1 x 4R7 in parallel to produce a single 1 ohm resistor with a rating of 1 watt (if each resistor is 0.25watt).
Place this resistor in the positive rail and connect your multimeter across it by selecting the 0v - 2.5v scale.
The 0v to 2.5v scale will now be: 0Amp to 2.5 amp (0mA to 2,500mA).
The resistors will get very hot above 1amp so you have to take very brief readings.

Some circuits fail to work when an ammeter is connected in the normal way and the arrangement we have suggested with the 4 resistors will fix the problem. It introduces a much-lower impedance to the circuit.
The leads of the meter are not included in the circuit and when the project is operating at high frequency, the leads don't form an additional impedance to upset the current-reading on the meter.

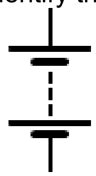
Some QUESTIONS ANSWERED:

A project requires 100mA but the **Power Supply** will deliver 1Amp. Will this "burn out" my project?
If the **Power Supply** is 12v and the project requires 12v, the project will take 100ma and NOT burn out.
You can connect a 12v device that takes 10mA and it will take exactly 10mA. The project determines the current-flow (providing the voltages are correct).
What happens if I connect a **Power Supply** to my project "around the wrong way?"
Some projects will be damaged. That's why you use "dry cells" for a Power Supply as the small current they will deliver will not damage the project.
What happens if I connect a 12v Power Supply to a 6v project.
Most projects will take a **LOT MORE** current when the voltage is higher than specified. The "over and under" voltage should NOT be more than 1v to 2v.
What will happen if I connect my 12v 1amp **Power Supply** to a project that needs 2Amp?
The project will work and not be damaged. It will not produce full brightness or full volume and the input voltage will possibly be 10v to 11v, due to the project OVERLOADING the power supply.
I can hear "hum" in the background of my amplifier.
The **Power Supply** does not have enough smoothing. Try a battery
Can I connect my 12v **Power Supply** in series with a 12v battery to get 24volts? Yes.
Can I connect my 12v Power Supply to a 12v battery to charge it?
A 12v battery needs over 15v and a 100 ohm resistor in series to charge it. A 12v Power Supply will not provide sufficient voltage.
How can I make a 5v and 9v Power Supply?
The easiest and cheapest way is to use dry cells. Or you can build a circuit using an adjustable 3-terminal regulator. It is not a good idea to put a resistor in the positive lead of a 12v supply to drop the voltage as you don't know the exact current that will flow and the voltage may be higher or lower than expected.
The voltage of my 12v supply drops to 10v when I connect my project.
The current-flow is more than the supply will deliver. We mentioned above that the transformer windings have a small resistance and the voltage is being dropped across the secondary winding when a current flows. Build the simple **Bench Power Supply** shown in **Fig 16** above.

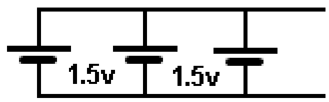
A good Power Supply is classified as a **LOW IMPEDANCE DEVICE** and the concept of charging a battery and using it to deliver the voltage and current will produce a **VERY LOW IMPEDANCE POWER SUPPLY**. In other words we are producing a power supply capable of delivering a **HIGH CURRENT**.

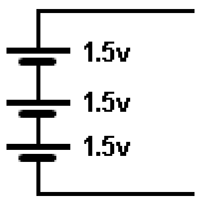
POWER SUPPLY TEST - 1

1. Why are cells placed in SERIES?
2. What is the voltage when 6 dry cells are placed in SERIES?
3. Identify the positive of the battery symbol:

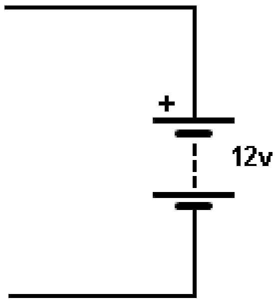


4. A battery will deliver VOLTAGE and ______________
5. What is the output voltage of these:

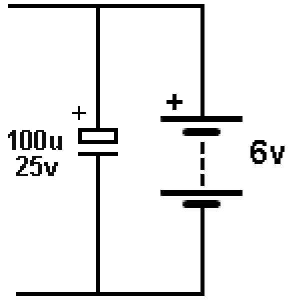




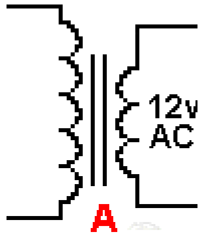
6. Can you connect two 9v batteries in SERIES?
7. Name the top and bottom rails:

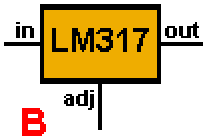


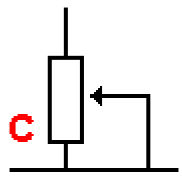
8. Name the component across the rails:



9. Name these components:







10. What is the purpose of putting an electrolytic across the power rails?
11. Name the three sections of a simple mains power supply:

____

____

____

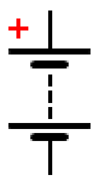
12. A bridge rectifier in a power supply produces a half-wave supply or full-wave supply?

13. When does the highest current flow:
A. OPEN CIRCUIT B. SHORT CIRCUIT C. CLOSED CIRCUIT

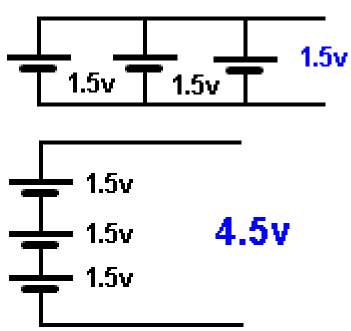
14. What do the letters "**AC**" stand for?
15. Should a battery have a **HIGH INTERNAL IMPEDANCE** or **LOW INTERNAL IMPEDANCE**?
16. The voltage of a battery can be measured with a Multimeter set to ________ range.

POWER SUPPLY TEST - 1 ANSWERS

1. To increase the output VOLTAGE
2. 9v
3.

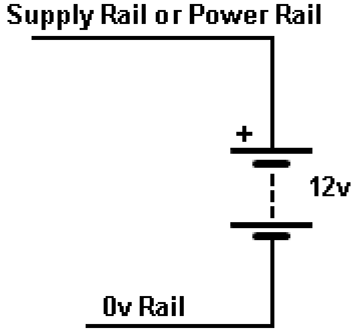


4. A battery will deliver VOLTAGE and CURRENT
5. The output voltage:

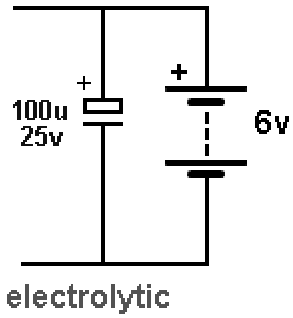


6. Two 9v batteries in SERIES produces 18v battery

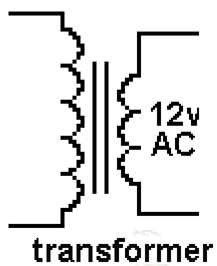
7. The top and bottom rails:

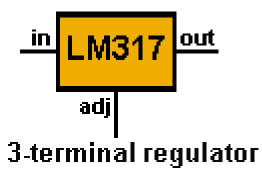


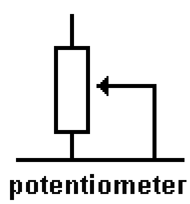
8. The component across the rails:



9. These components:







10. An electrolytic across the power rails will reduce ripple, spikes, distortion, reduce noise from one section entering another section, "tighten up the rails," reduce the impedance of the battery.
11. transformer, rectifier, filter
12. A bridge rectifier in a power supply produces a full-wave supply.
13. SHORT CIRCUIT
14. "**AC**" = Alternating Current
15. A battery should have a **LOW INTERNAL IMPEDANCE**
16. The voltage of a battery can be measured with a Multimeter set to "**V**" (volts) range.

RECAPPING

Whenever you are dealing with a **Power Supply** or **Power Rails**, you are dealing with a **LOW IMPEDANCE CIRCUIT**.
A **Low Impedance Circuit** does not rise and fall when the current increases and decreases.
It does not allow spikes from one part of a circuit to be transferred to another section.
And it is capable of delivering a HIGH CURRENT.

There are many ways to produce a Low Impedance Circuit and the simplest is to add capacitors (electrolytics).
Other methods of keeping the rails "**tight**" include using thick wire for the leads, wide traces on a printed circuit board and keeping the traces (printed wiring) as short as possible.
If a problem still exists, replace the supply with a set of rechargeable cells and shorten the leads to the battery. Remove plugs, sockets and switches during the test and don't monitor the current as the leads of the multimeter will introduce a lot of extra impedance.
This is especially important in high-frequency circuits as the power-rail is acting as an unwanted radiator for the signals and if these are long and thin, more of the signal gets radiated to the air and is lost. You only have to increase the leads to the battery on a 100MHz transmitter by 3cm and the output falls by 50%.
When measuring the current of a fly-back oscillator that is illuminating a LED, the illumination will drop due to the added impedance of the multimeter leads.
These examples show how a short "track" "trace" or "lead" will have a very big effect on the impedance of a circuit.

The power supplies we have covered in the circuits above are the best and cheapest.
Many Basic Electronics Courses go into far too much detail on Power Supplies. The chances of using a simple Linear Power Supply in a project is remote.
Linear Power Supplies are very expensive, large, wasteful, designs and the more-compact **S**witch-**M**ode **P**ower **S**upply is cheaper, lighter, higher-current and much more efficient.
The output of a **Plug Pack** has up to 5v ripple whereas a **SMPS** has less than 50mV.
However there are some **BUILDING BLOCKS** associated with power supplies that can be used in other parts of a project and are very interesting.

Note:
1. These "Building Blocks" have a number of different names for the same design and by changing a few components, they will operate in a completely different way.

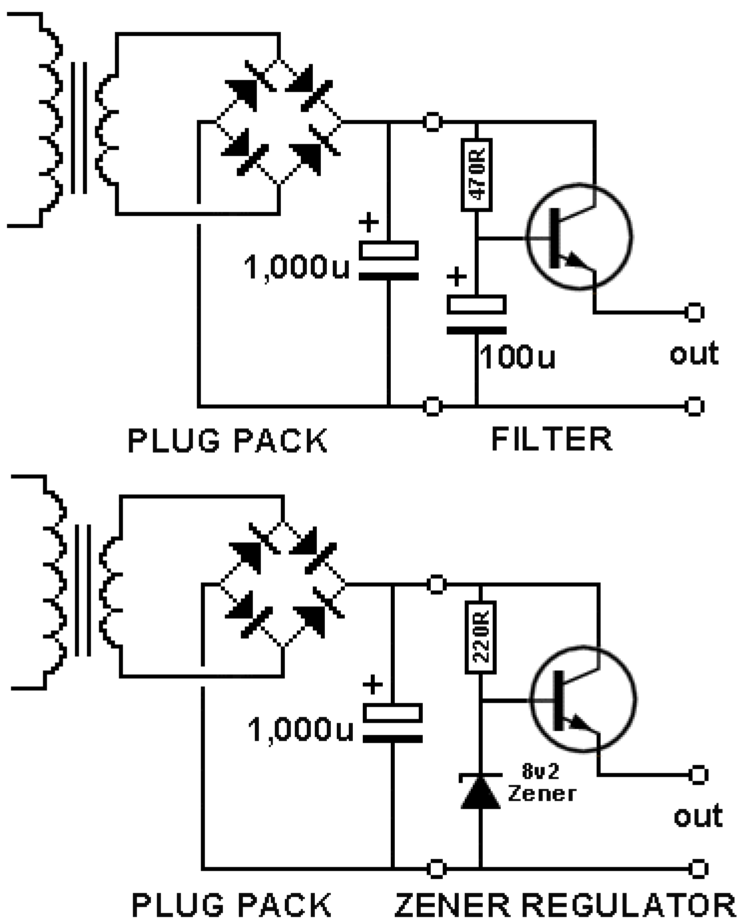


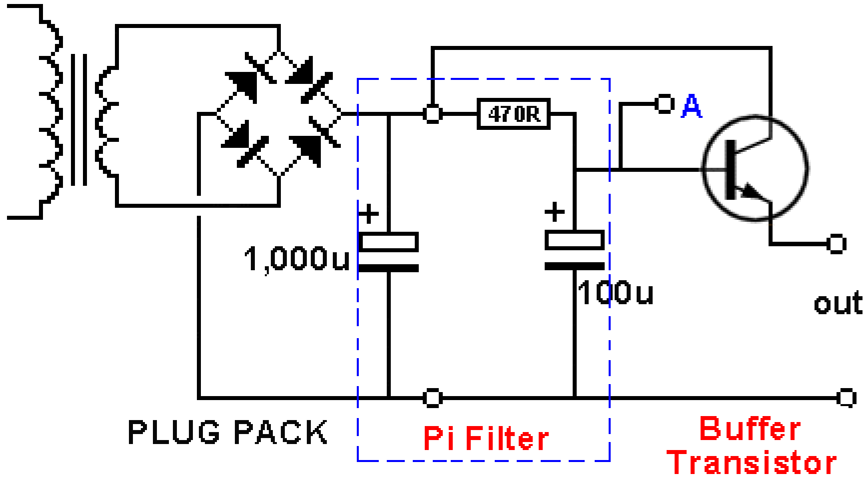
Fig 20. The PASS TRANSISTOR . . . also known as: THE ELECTRONIC FILTER

These two circuits are very similar in the way they operate but the zener diode produces a FIXED output voltage as well as a smoothing feature.
The electrolytic just smoothes the output voltage and does not provide any REGULATION. It

does not Regulate the output voltage. It does not "control" or "fix" the output voltage. The output voltage rises and falls as a result of the capability of the Plug Pack to deliver the current. As the current rises, the output voltage of the Plug Pack falls but the ripple is reduced by a factor of about 100x due to the "Electronic Filter" components.
The first three components are contained inside the Plug Pack and the 3 filtering components are connected to the leads of the Plug Pack. They can be considered a "Building Block." They reduce the ripple and provide a stable voltage that is lower than output of the Plug Pack by about 5v.
Both circuits are a form of **PASS REGULATOR** as the current "passes" through the transistor. Another type of regulator is the SHUNT REGULATOR where the current is shunted (sent) to the 0v rail and you can "tap off" this "wasted current" and use it in a circuit. The Shunt Regulator is very wasteful.
The **Series Pass Regulator** is exactly the same as the **Common Collector Amplifier** or **Emitter Follower** stage covered in the first part of this course.
A signal on the base will appear on the emitter with 100 times more strength.
But suppose there is NO signal on the base. This means the emitter will have NO signal (no ripple) and be 100 times stronger.
This is simple reasoning that has NEVER been explained in any text book.
The **base is fixed** and so the **emitter is fixed** and it does not matter what happens to the collector voltage. The ripple on the collector is not present on the emitter.
The first circuit is "floating" and the output voltage will depend on the voltage of the Plug Pack and the current required by the load.
Assume the load is 1 amp. This current will produce a ripple of about 5v as explained above. The base current will be 1,000 / 100 (the gain of the transistor) = 10mA. The 470R and 100u form a SERIES filter and will theoretically reduce the ripple to LESS than 1%. If the supply ripple is 5v, we will see what result we get.
The voltage drop across the transistor will depend on the current required by the load and when 1 amp is flowing the voltage-drop across the 470R will be: 470R x 0.01Amp = 4.7volt. The base-emitter drop is 0.6v and the output voltage will be 5.3v lower than the Plug Pack voltage.
This means the output of a 12v Plug Pack will be 6.7v and if the load is taking 1 amp, the ripple will be 5v / 100 (the gain of the transistor) = 50mV.
The dropper resistor in the second circuit is 220R and if the output of the Plug Pack is 12v, the drop across the resistor is 3.8v. The current into the zener will be 17mA. The transistor will "rob" the zener of 10mA and provide an output voltage of 7.6v
The filter sections will provide 100x reduction in ripple however a 5v ripple will be too high for the filter and more than 50mV will appear on the output.
Note how the transistor is drawn in the circuit. The emitter is drawn lower than the output of the Plug pack. This has been done to remind you that the output voltage will be lower than the plug-pack by a few volts. For 1Amp supply, the transistor will need to be rated at 2Amp or more so it is not overloaded.
BD139 transistors are rated at 1.5Amp but the gain is less than 100 @150mA and will be less than 20 at 1 amp.
TIP31A and TIP41A will handle 3A and 6A but the gain figures are under 100.
Obtaining a suitable transistor is very difficult and this circuit is really not practical.
The transistor we used in a prototype was BD679 (a Darlington transistor) rated at 6 amp and plenty of gain. It fits directly into the c, b, e, of the schematic but the symbol will need to be replaced with a Darlington symbol.

Some **Basic Electronics Courses** include theory on filters known as **"Pi Filters."** These are resistors, capacitors and inductors arranged to form the Greek letter "pi" - π).

(Remember: the circumference of a circle =$2\pi R$)
Although these arrangements do work, they are only 1% to 10% efficient as the **Electronic Filter** shown above in Fig 20.
Fig 20 is a pi-filter with a transistor buffer.
Here is the circuit re-arranged so you can see the "pi" section:



We explained the Pi section has a filtering capability of 100x for 10mA (the base current). When you compare this to 1,000mA it is only 1% of the required output current. If the 100u is increased to 1,000u, the output at A will be 10% of the capability of the Electronic Filter.
If the 100u is increase to 1,000u and the current is increased to 1,000mA, the voltage drop across the 470R will increase **100 times** and the pi filter as shown will be quite worthless.
If we replace the resistor with an inductor, the voltage-drop across the inductor will be less, but the size of the inductor will be ENORMOUS. The cost will be high and the ripple will be about the same as the RC filter.
Inductors have very little effect when the frequency is about 100Hz. But when the frequency is 40kHz, they have an improved effect of "400 times." That's why they are used in high frequency circuits.

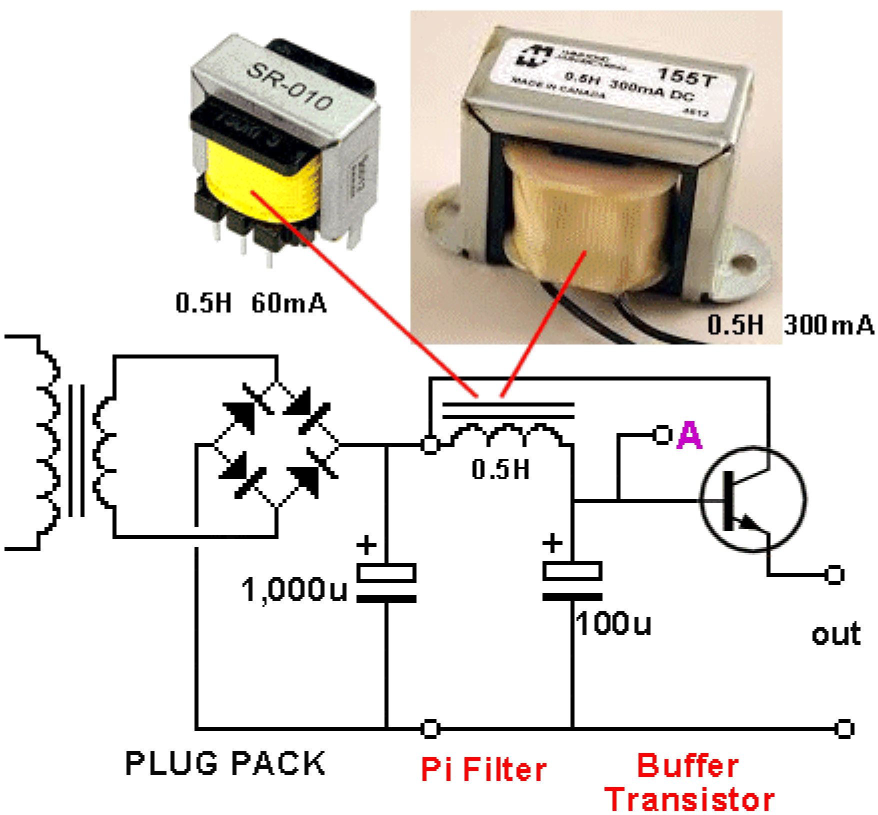
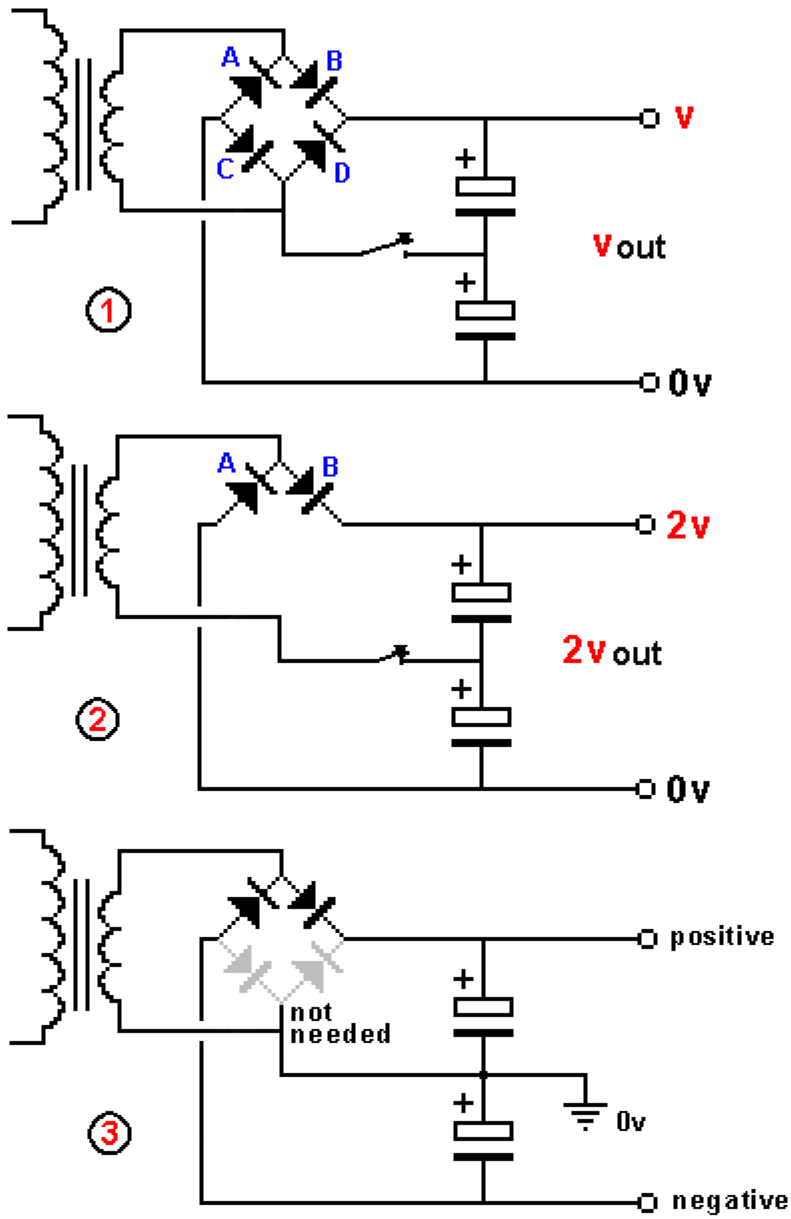


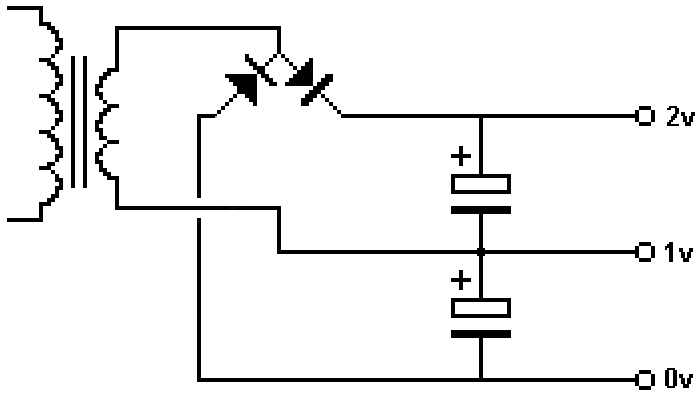
Fig 20a. The Pi Filter



Here's a power supply circuit that creates three different outputs, depending on how you connect to the output and how the transformer is connected. By closing the switch in circuit 1, the output voltage doubles.
In the first circuit, the bridge is supplying two electrolytics connected in series. The output voltage is "V" and is about 1.4 times the voltage of the transformer.
When the switch is closed (in the first circuit) the output voltage is DOUBLED.
At the same time, an interesting thing happens. Two of the diodes are not needed.
The second circuit shows only diodes A and B are needed. The circuit is a full-wave voltage divider but the top electrolytic is charged via the positive half of the waveform and the lower electrolytic is charged via the negative half of the waveform. This means it is really a half-wave power supply.
The third circuit connects the join of the two electrolytics to "earth" to produce a positive and negative supply - with each being a half-wave supply.   Since it is identical to circuit 2, the two lower diodes are not needed.

Fig 21. The Voltage Doubler and "+" & "-" Outputs

By re-arranging the outputs on circuit 3 above, we can get "v" output and "2v" output. Each output is a half-wave supply. The output voltage "v" is approx 1.4 times the AC voltage of the secondary winding.



By adding two diodes and two electrolytics, the circuit can produce "v" from a full-wave rectifier and a weak boost of 2v via a capacitor "charge-pump."

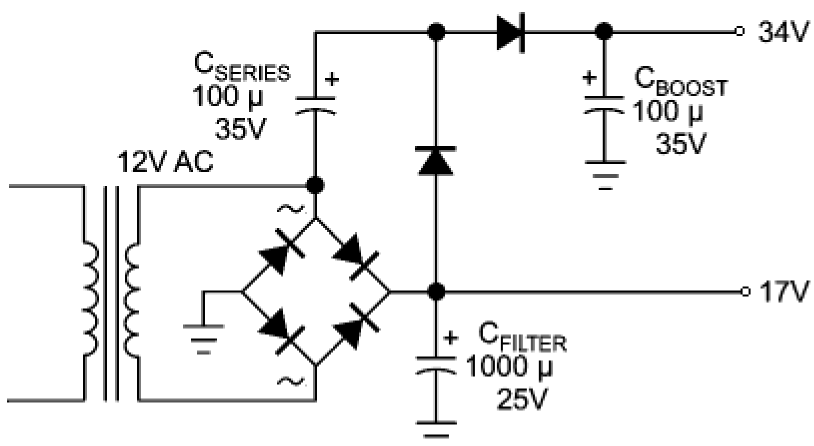
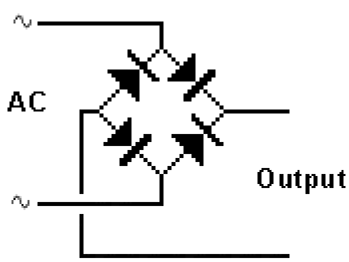
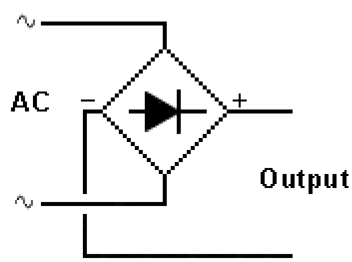


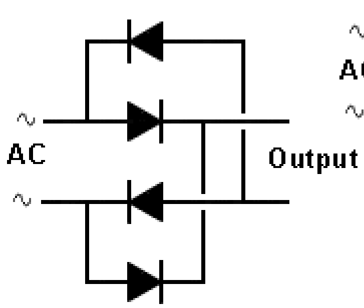
Fig 22. More Voltage Doubler Circuits

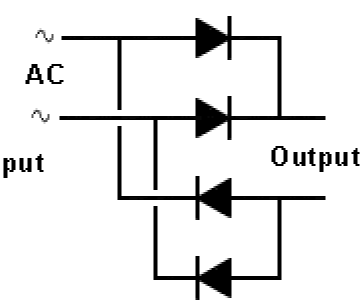
From the previous frames you can see a circuit can perform differently by merely changing one or two connections or adding one or two components.
That's why it is important to make sure the operation of the circuit is clear and is laid out in a way that can be easily recognised.

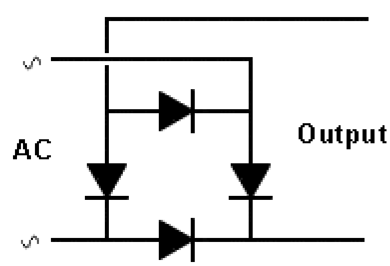




By drawing all the diodes in one direction, they can be replaced with a single diode in a diamond.
Here are three layouts that will take a few minutes to work out:

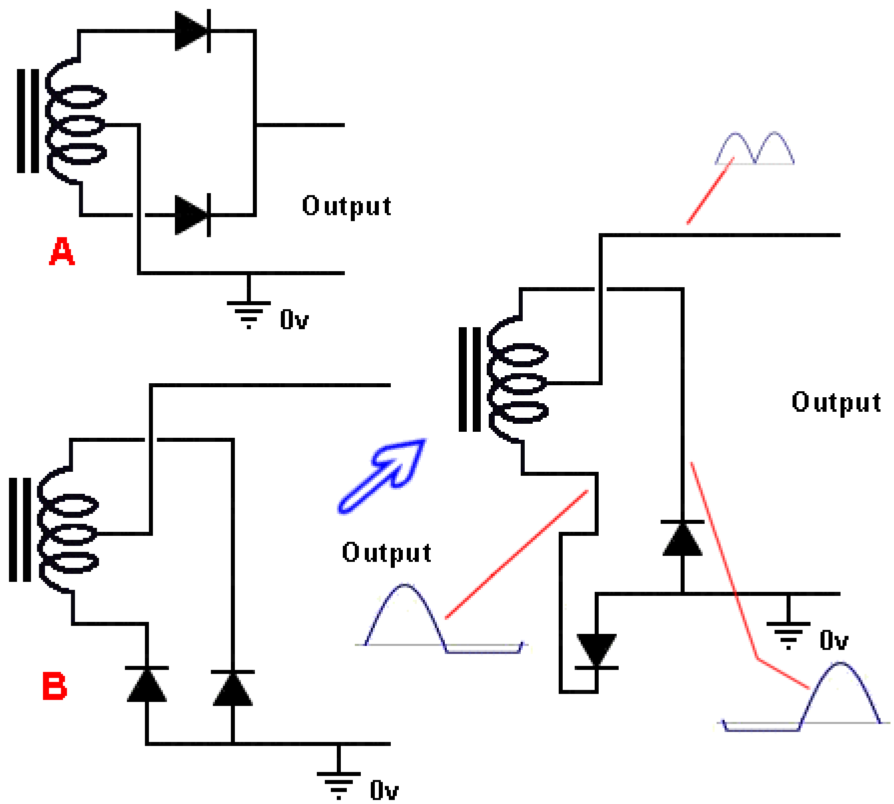




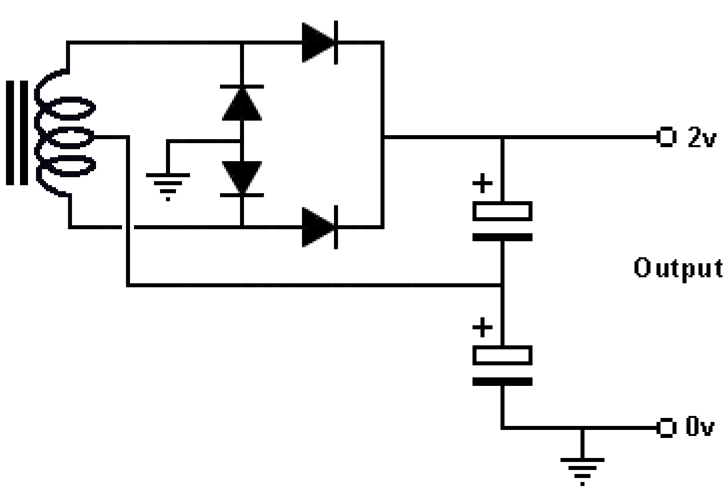


Normally a circuit is drawn so it is easy to see what is happening. But sometimes a re-

arrangement can be helpful.
The normal way to show the output of a centre-tapped secondary is Fig **A**. But re-arranging it to Fig **B** shows the diodes can be heatsinked on the earth-plane (chassis).



The animation of circuit B show the first diode gets "flipped over" as soon as the bottom winding of the transformer becomes negative and this puts the diode in "forward bias" where it starts to conduct and a maximum of 0.6v develops across it. This prevents the bottom winding moving any further and the centre-tap and top output increase in voltage. Note the voltage of the top winding is double the voltage on the centre-tap. But the voltage on the top winding simply goes to the other diode and nothing happens (the diode is put into "reverse-bias bias" mode and the voltage "sits" on the cathode and does nothing). This gives the centre tap an output to deliver current to the next section of the circuit (possibly a filter section). Exactly the same thing happens with the other portion of the waveform.
There is a lot to understand in this animation. The output "pushes" against one of the diodes that is forward biased and thus it will drop 0.6v and create a "rigid point" for the waveform to push out the other winding and into a filter section. At the same time the other winding is supplying twice the voltage to the unused diode and nothing further is happening as the diode is reverse biased.



It will take a minute to work out if the circuit on the left is a voltage doubler or a full-wave supply:

(It's a voltage-doubler via two half-wave supplies. Two of the diodes are not needed, as explained above.)

Fig 23. Re-arranging A Circuit

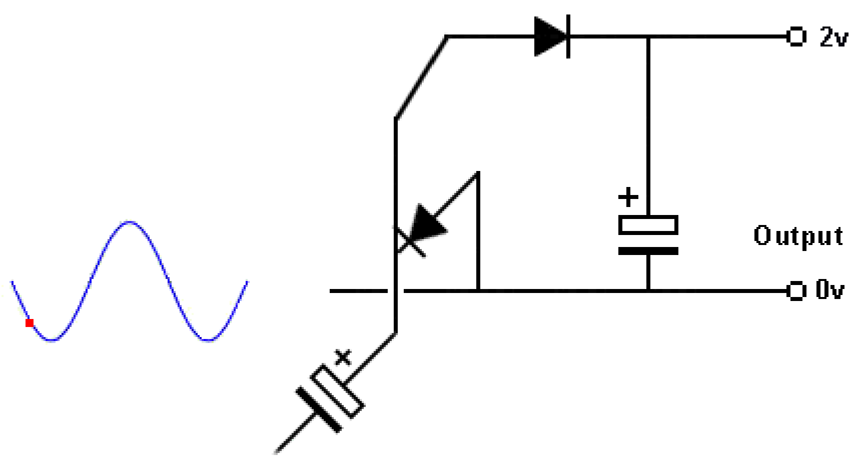
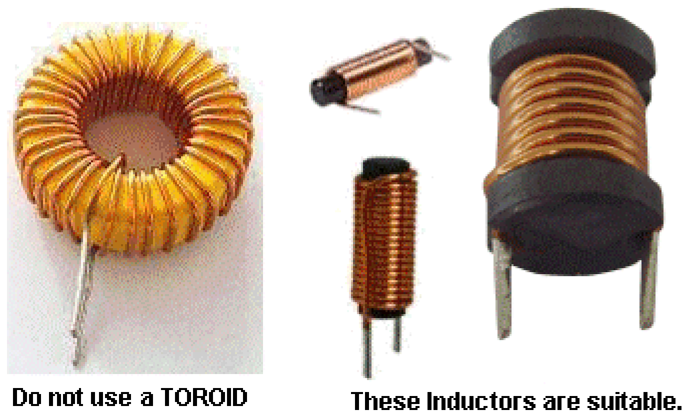


Fig 24. Voltage Doubler Animation

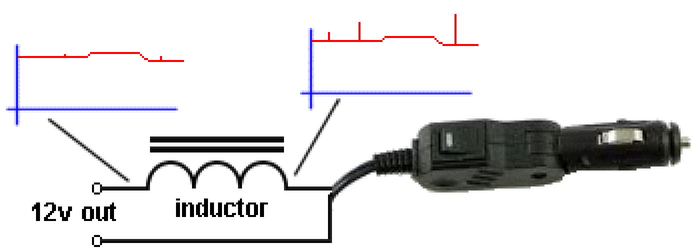
The animation shows a capacitor being charged via an input waveform and then being "jacked-up" by the waveform to deliver its voltage to a storage section made up of an electrolytic. The result is a voltage that is about twice the amplitude of the incoming waveform.

There is one more topic in this section.
It's **SPIKE SUPPRESSION**.
Suppose you are connecting to a battery in a vehicle and the supply has a lot of noise from the ignition and generator (alternator).
This noise can be as high as 40v and the requirement is to suppress this noise while allowing a current of up to 5 amps to flow.
The filtering covered above removed a 5v ripple by dropping it across a filter network but we now have a 12v (up to 15v) supply and require ALL the voltage to pass to our equipment.
In other words we need a filter-network with ZERO voltage-drop.
This is only possible with an INDUCTOR.
An INDUCTOR is a coil of wire on a core made of iron or ferrite. These are the same material and they are able to absorb a lot of magnetic flux 3,000 to 10,000 times more flux than air.
The first thing you do when choosing an inductor is select a wire that will allow the 3 amp current to flow. You need thick wire for 3 amp as thinner wire has more resistance (per turn) and it will heat-up to create a very warm inductor.
Next you have to wind say 30 turns on a ferrite core and try it.
There are no examples in any catalogue of how an inductor will perform in a circuit with spikes. There are lots of formulae but these are worthless as no-one has used a formulae and applied it to any of their inductors.
The inductor we are using will not get rid of ripple or fluctuations in the supply. It will only remove "spikes." A spike is a very fast, brief, pulse and it has a high amplitude.
As this high amplitude wave enters the first turn of the inductor, it allows a high current to flow and this produces a high magnetic flux. The magnetic flux cuts the other turns of the coil and this produces a voltage in each of the turns that is in the opposite direction to the incoming voltage.
When the spike enters the second turn of the coil it sees a back voltage that cancels some of the incoming voltage. Thus the current it can produce is less and the flux it produces is smaller.
This continues for each turn of the coil and by the time the spike reaches the end of the inductor it is zero. (This is a description to make it easy to understand how the inductor works. It is not entirely in accord with the actual production of the magnetic flux).
No other components are needed as the inductor suppresses the spike.
Provided the inductor has sufficient number of turns, the spike will be suppressed. A small voltage-drop (mV) will develop across the inductor due to the 3 amp current-flow.
Each turn on an inductor can suppress between 1v to 10v so you have to wind a number of turns on a core and try it.
Adding an inductor is a form of DECOUPLING. You are separating the battery from your

supply and preventing spikes up to 40v entering your equipment. The rails are already very "tight" as you can draw over 100amps via a cigarette lighter socket and that's why a 20 amp fuse is provided in the vehicle.
Other terms for the inductor include: LINE CONDITIONING, LINE FILTERING, SPIKE SUPPRESSION - but not Surge Suppression or Voltage Regulation. The output voltage of a cigarette-lighter socket will go as high as 15v - 16v, depending on the condition of the battery and the charging via the alternator.



Do not use a **TOROID**. The DC current through the winding will create magnetic flux that will saturate the core and the spike may not be absorbed.



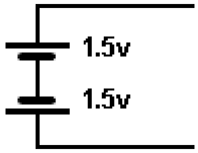
The inductor will reduce the spikes but not the ripple or fluctuations in the 12v.

Fig 25. Spike Suppression Inductor

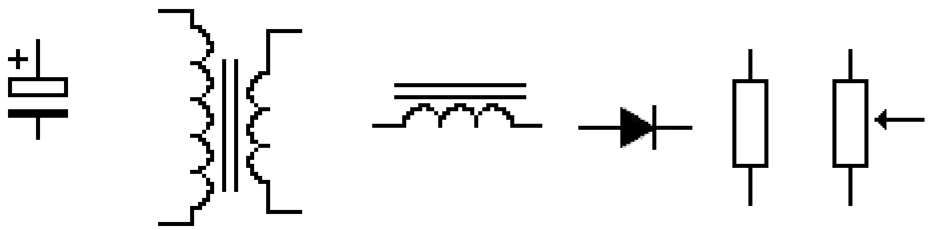
A 1-amp **Linear Power Supply** is a reasonably difficult power supply to build.
1 amp diodes (such as 1N4004) are really only suited to 750mA as the voltage across them increases as the current increases and at 1 amp, the voltage-drop is 1.1v. This gives a wattage dissipation of over 550mW as each diode is conducting for half the time in a full-wave supply.
The diodes will get very hot and need heatsinking.
The ripple from a 1-amp supply with 1,000u will be 5v p-p and 2,200u is needed for 2v p-p ripple.
The output needs further filtering and regulation to make it suitable for most electronic circuits and all this can be done with a low-cost **Switch-Mode Power Supply**.

POWER SUPPLY TEST - 2

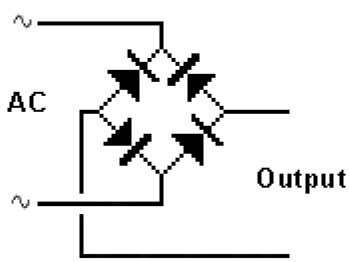
1. What is the output of this circuit:



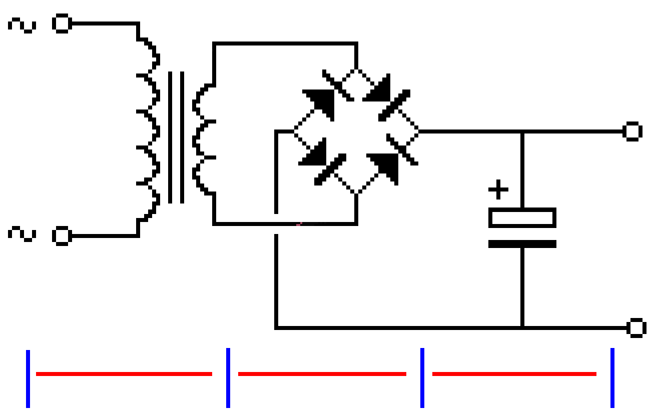
2. What is the output voltage of four 1.2v rechargeable cells in SERIES:
3. Can cells be connected in PARALLEL?
4. How many cells in a 9v battery?
5. Is it dangerous to touch the NEUTRAL lead of the MAINS?
6. What is the name given to the term: "cycles per second"?
7. Name two types of capacitor
8. Name the component contained in a "bridge."
9. What is another name for a LINEAR REGULATOR
10. Name these: "v" "mA" "R" "k"
11. What is the approx voltage-drop across a power diode?
12. Is current measured "across a battery" or via a "cut in the circuit."
13. Most plug-packs employ: Half-Wave Rectification or Full-Wave Rectification.
14. Name these symbols:



15. Will this bridge produce an output?



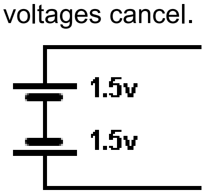
16. Name the 3 sections:



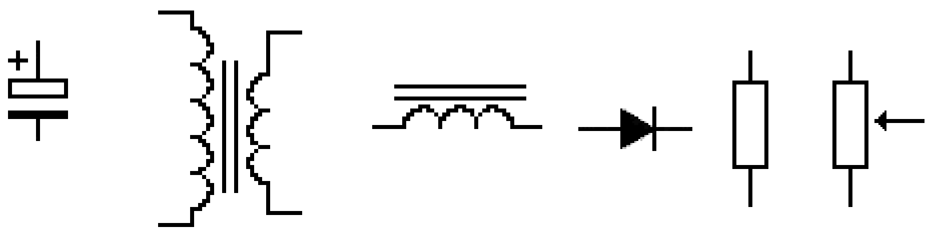
17. What is the approx value of capacitance for the electrolytic in a 1amp power supply.
18. What is the name given to improving the ripple from a Plug Pack.

POWER SUPPLY TEST - 2 Answers

1. The output of this circuit is ZERO because one cell is around the wrong way and the voltages cancel.

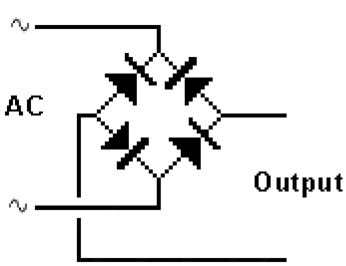


2. The output voltage of four 1.2v rechargeable cells in SERIES is 1.2v x 4 = 4.8v or 1.5v x 4 = 6v or 3.6v x 4 = 14.4v
3. Can cells be connected in PARALLEL? Yes
4. How many cells in a 9v battery? Six
5. Is it dangerous to touch the NEUTRAL lead of the MAINS? No. But the wires may be connected incorrectly and the neutral may be the ACTIVE. Never take a risk.
6. What is the name given to the term: "cycles per second"? Hertz Hz.
7. Name two types of capacitor: Ceramic and Electrolytic
8. Name the component contained in a "bridge." Four DIODES
9. What is another name for a LINEAR REGULATOR - 3-Terminal Regulator, Regulator,
10. Name these: "v" "mA" "R" "k" Volts, milliamps, Ohms (resistance), kilo ohms
11. What is the approx voltage-drop across a power diode? 0.6v to 1.1v
12. Current is measured via a "cut in the circuit."
13. Most plug-packs employ Full-Wave Rectification.
14. Name these symbols:



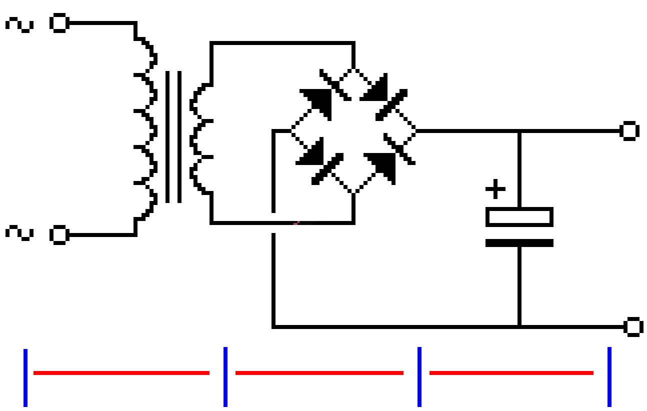
electrolytic transformer inductor, choke, coil diode resistor potentiometer

15. Will this bridge produce an output?



One of the diodes is around the wrong way (top, right diode)

16. Name the 3 sections:



CONVERSION RECTIFICATION SMOOTHING

17. What is the approx value of capacitance for the electrolytic in a 1amp power supply: 1,000u
18. What is the name given to improving the ripple from a Plug Pack.
Filtering, buffering, regulating, smoothing, using a PASS Transistor, electronic filtering, Ripple Suppression,

HOW TO USE A POWER SUPPLY

You must be very careful when designing and testing a circuit on a **POWER SUPPLY**.
When we talk about a **POWER SUPPLY** we mean a **BENCH SUPPLY** or **BENCH POWER SUPPLY** or **REGULATED POWER SUPPLY** or **CURRENT LIMITED SUPPLY** or **TEST SUPPLY**.
These are all names for a Power Supply fitted to a test bench and may be as simple as a Plug Pack, Battery Charger, Regulated Supply, Dual Supply, Dual Tracking Supply or Digital

Supply.
Here are some photos of the type of equipment you may use:

Power Supply with "Meters"

Plug Pack Regulator
built by a reader

A Power Supply project by:
http://www.ecrostech.com/General/MiniPsu/Bench.htm

When using a **Bench Supply** (any of the above), it is important to remember that it MUST be **EXACTLY THE SAME** as the supply you will using for the project, if you want to get accurate results.
If you are using AA cells in the project or rechargeable cells, 3.6v Li-ion cells, button cells, coin cells, 12v rechargeable battery or solar cells, the Bench Supply will produce different results.
This is because the IMPEDANCE of each supply is different.
In other words, the ability of each supply to deliver peaks of current will be different.
The circuit may work completely differently on Solar Cells and you are wasting your time designing it on a Power Supply.
If the project will use a 12v rechargeable battery, designing it with a battery on long leads with meters included, will produce completely different results. Even the on/off switch can make a difference.

That's why it is recommended to use exactly the same supply as will be used in the final design of the project.
This all comes down to the need for an expensive Bench Supply.
No project will incorporate an expensive supply, and thus a "showy" Bench Supply may look impressive, but "function-wise" a set of AA cells is all that's required.

When designing a project on a Test Bench, the leads to the power supply and meters, may introduce additional resistance and if the circuit is operating at high frequency or requires pulses of high current, this resistance can change the operation of the circuit to a point where it will fail to work. This happened with a Flashing Beacon Multivibrator circuit driving 18 watt lamps. The additional resistance of the leads prevented the circuit flashing. The reason is this: Lamps take 6 times more current to turn ON and this current produced a voltage-drop that prevented the circuit flashing.
The secret to the operation of many circuits is "tight power rails" and this requires short leads and electrolytics or capacitors in a number of critical places.
Using a set of cells on short leads or a rechargeable battery on short leads allows you to see the exact impedances you are dealing with, whereas a power supply with internal meters and

current limiting will have an unknown "hidden" impedance.

ONE LAST HINT

The best way to design a project is with a set of AA cells and also a set of "used" cells.
This will give you an idea of how the project will work during the life of the battery.
Cells are only "fresh" for a short period of time and most of the use is carried out at a reduced voltage.
You need to know how the project will work during this time and find out if any faults develop.
A set of AA cells will not be capable of delivering a high current and if a "short" develops during designing, nothing will be destroyed.
All this is a reflection of over 40 years designing electronic projects and overseeing new developers starting with an impressive "current limiting" Power Supply and wondering why the project (an amplifier) did not work successfully on batteries.
The supply was a constant 12v, whereas a set of cells soon drops to 10v and the performance of an amplifier falls considerably.

What does CONSTANT VOLTAGE mean?

We normally don't talk about **Constant Voltage** from a Power Supply because we assume the power supply will be suitable for the requirement and deliver the "dialed" voltage over the range of current we are requiring.
If the power supply is good-quality, a 1 amp supply will deliver up to 1 amp at say 12v with ripple as low as 5mV and the voltage will not drop below 11.95v.
Obviously a Plug Pack is not **Constant Voltage** as we have said the voltage will drop 3v - 7v and the ripple will be as high as 5v peak-peak.

In the photo above, the B&K **Power Supply** can be adjusted from 0v to 30v and 0 Amp to 3 Amp.
Your project is connected via a red lead and black lead and banana plugs that push into the sockets on the front.
You then "dial up" say 12v using the coarse "voltage" control and then dial up the current via the coarse "current" control.
If your project requires 100mA, and you dial up 200mA, the project will work perfectly and the voltage will remain constant.
None of the special features of the power supply are being used.
In other words the Power Supply is "stronger" than what you need.
The voltage will remain at 12v and this is called **CONSTANT VOLTAGE.**

What does CONSTANT CURRENT mean?

Constant Current really means **MAXIMUM CURRENT**.
If we take the same B&K power supply (shown above) and turn the current down to 100mA, the voltage will remain constant @12v but if the project is say an amplifier and you turn up the volume, it will want to take a higher current. The power supply will prevent your project taking more than 100mA and it does this by reducing the voltage.
In other words, the Power Supply is "weaker" than what you need and it cannot supply the

required current.
This is exactly what happens with a "used" battery. It will show 12v when tested with a voltmeter on NO-LOAD (amplifier not connected), but when the amplifier is turned up, the voltage from the battery will drop.
This is a simple explanation of the characteristic of a Power Supply called: **constant voltage/constant current automatic crossover**. The continuous transition from constant current to constant voltage in response to load change.
In other words the **VOLTAGE** is the "quantity" that is **maintained** until the "dialed-up" current is reached. Then the voltage **drops** so the **MAXIMUM CURRENT** (100mA in this case) is **not exceeded**.

Note: A **Power Supply** does not deliver a CONSTANT CURRENT to a Project.
The project determines the current and if it requires a LOWER CURRENT, the supply delivers the lower current. So, obviously, a Power Supply is not delivering a Constant Current and it never delivers a constant current unless the load is a fixed wattage such as a resistor. In all other cases it delivers **UP TO** the maximum current.
A **Power Supply** delivers a **MAXIMUM CURRENT** when in the **CONSTANT CURRENT** mode. When the project requires a higher current, the voltage to the project is reduced.

MEASURING VOLTAGE & CURRENT

When using a Power Supply, you need to 'SET" the voltage. This means you need to adjust the voltage to suit the project.
Sometimes this voltage is very critical.
Microcontrollers and TTL chips require a voltage between 4.5v and 5.5v for correct operation.
Other circuits and devices and chips can operate on supplies from 2v to 15v or up to 48v (such as phone-line voltage) and you will need to work out the most suitable voltage BEFORE connecting the project to a Power Supply.
You cannot always work out the supply voltage by looking at a project or a circuit diagram.
Sometimes a special chip may determine the low voltage (such as a microcontroller or TTL chip) and sometimes a motor or relay will determine the voltage.
If a project is designed for 12v, you should not increase the voltage by more than 2v as some sections of a circuit (especially the output stages) will take a lot more current when the voltage is increased.
Once you have determined the voltage, you can set up your project and connect it to a power supply as shown in the following diagram:

"Dial-up" 12.5v and 300mA for the project. The on-board 5v regulator will convert the 12.5v to 5v. The circuit requires a maximum of 200mA, so the 300mA capability of the Power Supply will allow the circuit to work perfectly and if a short-circuit occurs, the maximum current from the Power Supply will be 300mA.
The B&K Power Supply shown in the photo (and all Power Supplies with Constant Current feature) does not show the current taken by the project (unless the project is taking the full 300mA.) You have no idea of the current taken by the project and if the project taken more than 300mA, the voltage will drop but this may not show on the display as the display shows the "dialed" voltage.

To observe the current taken by a project, you will need to include an ammeter as shown in the photo:

PROBLEM:

If your project contains a globe (such as on the output) you cannot use a Power Supply with **CURRENT MONITORING**.
A globe takes up to 6 times more current to start to turn ON (because the filament is cold and has a LOW resistance) and the Power Supply will see this as a LOAD and reduce the voltage. The voltage may be so **LOW** that the rest of the circuit does not work and this will create a problem. You will think the circuit is FAULTY. Some Power Supplies have a LED to indicate it has gone into **CURRENT-LIMIT MODE**. In the example above, the globe is 36watt and takes 3 amp when illuminated. But it takes over 10 amp to start to illuminate and the supply has only a 5 amp rating.
The Multimeter is indicating 3.25 amp but the globe is not illuminating. The Supply has "shut down" to less than 4v because the **CURRENT LIMITING** circuit has reduced the output current to 3 amp and the only way to deliver 3 amp is to reduce the voltage to about 4v.
The **CURRENT MONITOR (current limiting circuit)** cannot be turned off and this supply is

not suitable.

You need a **HIGH CURRENT SUPPLY** to test a car globe.

Now you know why a 12v rechargeable battery and a set of AA cells can be used as a **BENCH SUPPLY.**

The Transistor Amplifier

Home

Save P1 as:
.doc (700kB) .pdf (600kB)

Save P2 as:
.doc (1.6MB) .pdf (1.2MB)

See: 1- 100 Transistor Circuits
101 - 200 Transistor Circuits

P1 P2 P3 test

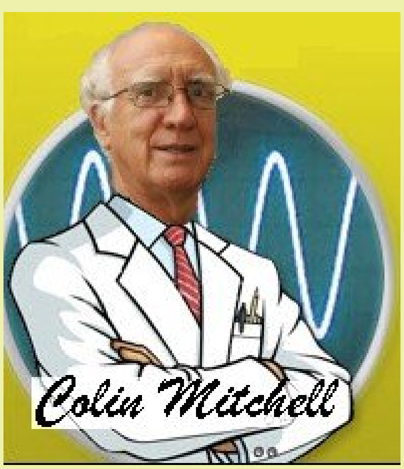
A simple explanation of how a transistor works in a circuit, and how to connect transistors to create a number of different circuits. No mathematics and no complex wording.
Just a completely different approach you can understand . . .

TOPICS:

More topics on P2

This eBook starts by turning **ON** a single transistor with your finger (between two leads) and progresses to describing how a transistor can be connected to the supply rails in 3 different ways.
Then it connects two transistors together DIRECTLY or via a capacitor to produce amplifiers and oscillators.
As you work through the circuits, the arrangement of the parts are changed slightly to produce an entirely different circuit with new features.
This way you gradually progress through a whole range of circuits (with names you can remember) and they are described as if the parts are "moving up and down" or "turning on and off."
Even some of the most complex circuits are described in a way you can see them working and once you get an understanding, you can pick up a text book and slog though the mathematics.
But before you reach for a text book, you should build at least 50 circuits . . . otherwise you are wasting your time.

I understand how the circuits work, because I built them. Not by reading a text book!



From a reader, Mr Ashvini Vishvakarma, India.
I was never taught the influence of the coupling capacitor in capacitor-

coupled single transistor stages.
No one told me that R_L of one stage delivers the input current of the next stage.
No text book has ever mentioned these things before because the writers have never built any of the circuits they are describing. They just copy one-another.
That's why this eBook is so informative. It will teach you things, never covered before.
I don't talk about "formulae" or produce graphs because transistors have a wide range of parameters - especially the gain - and this has the greatest effect on the operation of a circuit. It is faster to build a circuit and test a transistor than work out the "Q-point" from a load-line.
The same with two resistors in parallel. It is faster to put them together and measure the resistance, than look up a nomograph.
You learn 10 times faster with actual circuits than theoretical models and 10 times smarter when you know how to avoid mistakes.

Dear Colin,
After many attempts to grasp transistor biasing,
I did not get it until I eventually found your tutorial
on it! You put it so clearly and straight forward.
Best of all, you actually demonstrate with numerous
examples, step by step!
What a joy, to learn from your tutorial!
Thank you for this excellent article!

Kind regards

Jörg Rauh

TRANSISTOR TEST

Click HERE for a TRANSISTOR TEST

Here is **Electronics I** course from South Dakota School of Electronics.
These lectures cover the mathematical side of how various circuits work.
Once you complete this eBook, the lecture notes will be much easier to understand.

Lecture #	Title
0	Cover Page. Table of contents.
1	Ideal Diode.
2	Physical Operation of Diodes.
3	DC Analysis of Diode Circuits.
4	Small-Signal Diode Model and Its Application.
5	Introduction to *B2 Spice* from Beige Bag Software.
6	Zener Diodes.

7	Diode Rectifier Circuits (Half Cycle, Full Cycle, and Bridge).
8	Peak Rectifiers.
9	Limiting and Clamping Diode Circuits. Voltage Doubler. Special Diode Types.
10	Bipolar Junction Transistor Construction. NPN Physical Operation.
11	PNP Bipolar Junction Transistor Physical Operation. BJT Examples.
12	DC Analysis of BJT Circuits.
13	The BJT as a Signal Amplifier.
14	BJT Small-Signal Equivalent Circuit Models.
15	BJT Small-Signal Amplifier Examples.
16	Graphical Analysis of a BJT Small-Signal Amplifier.
17	BJT Biasing. Current Mirror.
18	Common Emitter Amplifier.
19	Common Emitter Amplifier with Emitter Degeneration.
20	Common Base Amplifier.
21	Common Collector (Emitter Follower) Amplifier.
22	BJT Internal Capacitances. High Frequency Circuit Model.
23	Common Emitter Amplifier Frequency Response. Miller's Theorem.
24	BJT as an Electronic Switch.
25	Enhancement Type MOSFET Operation, *P*-Channel, and CMOS.
26	MOSFET Circuit Symbols, i_D-v_{DS} Characteristics.
27	MOSFET Circuits at DC.
28	MOSFET as an Amplifier. Small-Signal Equivalent Circuit Models.
29	MOSFET Small-Signal Amplifier Examples.
30	Biasing MOSFET Amplifiers. MOSFET Current Mirrors.
31	Common Source Amplifier.
32	Common Source Amplifier with Source Degeneration.
33	CMOS Common Source Amplifier.
34	MOSFET Common Gate Amplifier.
35	CMOS Common Gate Amplifier.
36	MOSFET Common Drain (Source Follower) Amplifier.
37	CMOS Digital Logic Inverter.

My interpretation of the above-course is this:
It goes into **far too much detail** and far too much mathematics.
There is very little on digital concepts and nothing on microcontrollers.
Time would be much better spent on explaining transistor and MOSFET behaviour in a simpler way and getting on with digital circuitry and microcontroller projects. The student should build at least 20 projects for the year as this is the only REAL way to learn. I give the course 2/10. It really is a WASTED year. You simply cannot put a transistor into a circuit and expect it to produce the calculated results. The gain of a transistor can be from 100 to 200 in a batch and this changes the outcome by 50%!!
Instead of taking 30 minutes to work out the answer, simply build the circuit and measure the REAL result.

Let's Start:

THE NPN TRANSISTOR

There are thousands of transistors and hundreds of different makes, styles and sizes of this amazing device. But there are only two different types. NPN and PNP. The most common is NPN and we will cover it first. There are many different styles but we will use the smallest and cheapest. It is called a GENERAL PURPOSE TRANSISTOR. The type-numbers on the transistor will change according to the country where it was made or sold but the actual capabilities are the

SAME.
We are talking about the "common" or "ordinary" or original type.
It is also referred to as a BJT (Bi-polar Junction Transistor) to identify it from all the other types of transistors (such Field Effect, Uni-junction, SCR,) but we will just call it a TRANSISTOR.

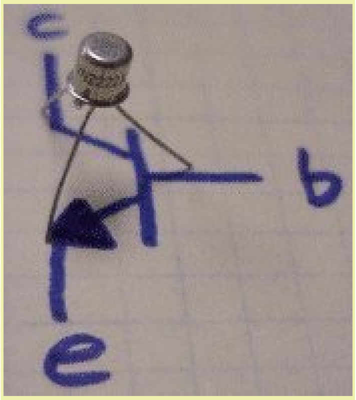


Fig 1. NPN Transistor

Fig 1 shows an NPN transistor with the legs covering the symbol showing the name for each lead.
The leads are BASE, COLLECTOR and EMITTER.
The transistor shown in the photo has a metal case with a tiny tag next to the emitter lead.
Most small transistors have a plastic case and the leads are in a single line. The side of the transistor has a "front" or "face" with markings such as transistor-type.
Three types of transistors are shown below:

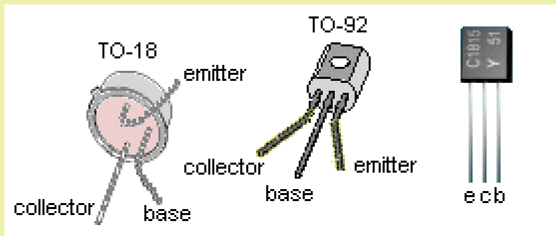


Fig 1a.

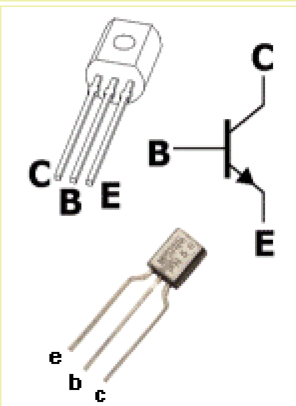


Fig 2. NPN Transistor Symbol

Fig 2 shows two "general purpose" transistors with different pinouts. You need to refer to data sheets or test the transistor to find the pinout for the device you are using as there are about 5 different pin-outs. The symbol for an NPN transistor has the arrow on the emitter pointing AWAY from the BASE.

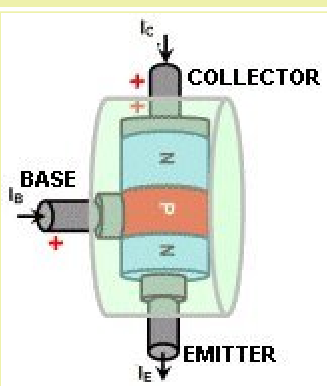


Fig 3 shows the equivalent of an NPN transistor as a water valve. As more current (water) enters the base, more water flows from the collector to the emitter. When no water enters the base, no water flows through the collector-emitter path.

Fig 3. NPN "Water Valve"

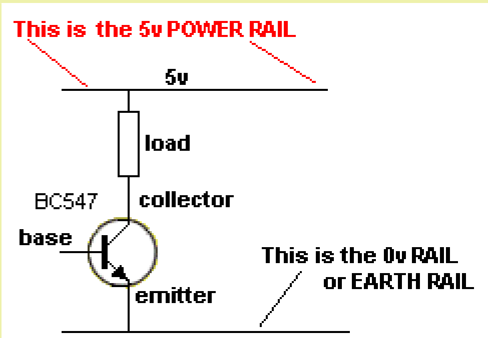


Fig 4. NPN connected to the power rails

Fig 4 shows an NPN transistor connected to the power rails. The **collector** connects to a resistor called a LOAD RESISTOR and the **emitter** connects to the 0v rail or "earth" or "ground." It can also be called the negative rail.
The **base** is the input lead and the collector is the output.
The transistor-type **BC547** means a general-purpose transistor.
Sometimes a general-purpose transistor is called **TUN** - for **T**ransistor **U**niversal **NPN**.
A general-purpose **PNP** transistor is called **TUP** - for **T**ransistor **U**niversal **PNP**.

Here is a video by Ben. He shows how to connect a solenoid to an NPN transistor:
Click at the top of the video to go to the **YouTube** website to see more electronics videos.

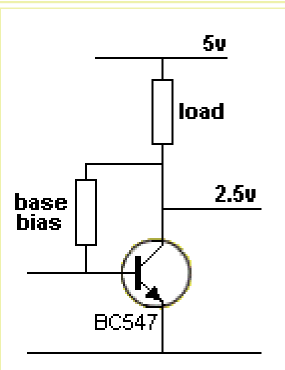


Fig 5. NPN Transistor biased with a "base bias" resistor and a LOAD resistor

Fig 5 shows an NPN transistor in SELF BIAS mode. This is called a COMMON EMITTER stage and the resistance of the BASE BIAS RESISTOR is selected so the voltage on the collector is half-rail voltage. In this case it is 2.5v.
To keep the theory simple, here's how you do it. Use 22k as the load resistor.
Select the base bias resistor until the measured voltage on the collector is 2.5v. The base bias resistor will be about 2M2.
This is how the transistor gets turned on by the base bias resistor:
The base bias resistor feeds a small current into the base and this makes the transistor turn ON and creates a current-flow though the collector-emitter leads.
This causes the same current to flow through the load resistor and a voltage-drop is created across this resistor. This lowers the voltage on the collector.
The lower voltage causes a lower current to flow into the base, via the base-bias resistor, and the transistor stops turning on a slight amount. The transistor very quickly settles to allowing a certain current to flow through the collector-emitter and produce a voltage at the collector that is just sufficient to allow the right amount of current to enter the base. That's why it is called SELF BIAS.

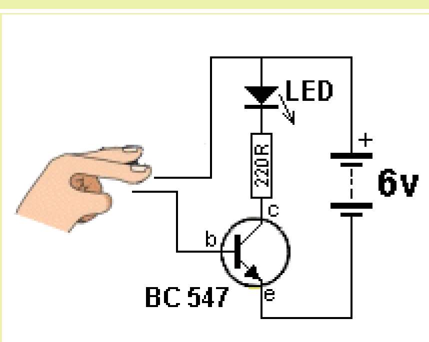


Fig 6 shows the transistor being turned on via a finger. Press hard on the two wires and the LED will illuminate brighter. As you press harder, the resistance of your finger decreases. This allows more current to flow into the base and the transistor turns on

Fig 6. Turning ON an NPN transistor	harder.

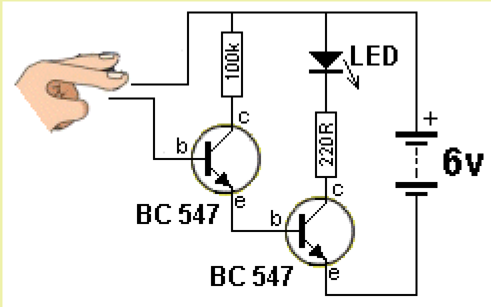


Fig 7. Two transistors turning ON

Fig 7 shows a second transistor to "amplify the effect of your finger" and the LED illuminates about 100 times brighter.

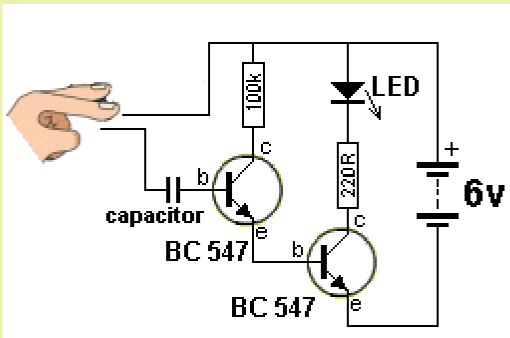


Fig 8. Adding a capacitor

Fig 8 shows the effect of putting a capacitor on the base lead. The capacitor must be uncharged and when you apply pressure, the LED will flash brightly then go off. This is because the capacitor gets charged when you touch the wires. As soon as it is charged, NO MORE CURRENT flows though it. The first transistor stops receiving current and the circuit does not keep the LED illuminated. To get the circuit to work again, the capacitor must be discharged. This is a simple concept of how a capacitor works. A large-value capacitor will keep the LED illuminated for a longer period of time as it will take longer to charge.

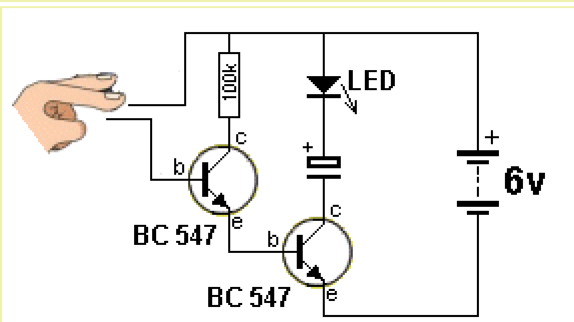
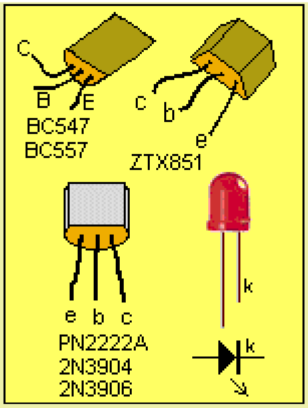


Fig 9. Adding a capacitor to the output

Fig 9 shows the effect of putting a capacitor on the output. It must be uncharged for this effect to work. We know from Fig 7 that the circuit will stay ON constantly when the wires are touched but when a capacitor is placed in the OUTPUT, it gets charged when the circuit turns ON and only allows the LED to flash.
The electrolytic must be manually discharged to see the effect again.

1. This is a simple explanation of how a transistor works. It amplifies the current entering the base (about 100 times) and the higher current flowing through the collector-emitter leads will illuminate a LED or drive other devices.
2. A capacitor allows current to flow through it until it gets charged. It must be discharged to see the effect again.

TRANSISTOR PINOUTS:



Transistor Pinouts

Just some of the pinouts for a transistor. You need to refer to a data sheet or test the device to determine the pins as there are **NO** standard pin-outs.

THE RESISTOR

Before we go any further, we need to talk about the RESISTOR.
It's a two-leaded electrical component that has resistance from a fraction of an OHM to many millions of ohms (depending how much carbon is in the resistor). When the resistance is very low (small) the resistor is equal to a piece of wire and when it is very high, the resistance is equal to . . . . . .
The value of a resistor is marked on the body with bands of colours or, in the case of surface-mount resistors, a set of numbers. These identify the value of the resistor in OHMs. When the value of resistance is above one-thousand ohms, we use the letter "k" - for example 1,200 ohms is 1.2k or 1k2. When the value is above one-million ohms, we use the letter "M" - for example 2,200,000 ohms is 2.2M or 2M2. When the value is say 100 ohms we use the letter "R" - 100R.
Resistors do "all kinds of things" in a circuit. In other words, they can join two components, separate two components, prevent a component from getting too hot, prevent an amplifier from overloading, allow a capacitor to charge quickly or slowly - and many more.
All these things can be achieved because a resistor has ONE SIMPLE FEATURE . . .

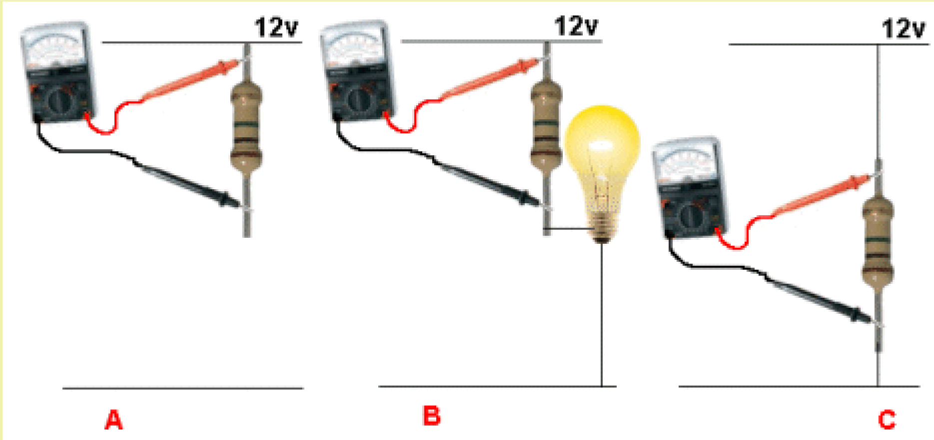
A resistor limits (or reduces) the current-flow.

That's all a resistor does. It limits - or controls - or allows - a current to flow according to the resistance of the resistor.

This **simple feature of limiting the current** is like a man with a hammer - he can hammer nails, break glass, drive a pole into the ground and lots more and a resistor can do more than 12 different "things."

When a **current flows through** a resistor, a **voltage is developed across** it. This voltage is called the **VOLTAGE DROP**. (It is also called the VOLTAGE **LOST** ACROSS THE RESISTOR).

The following 3 examples will help you understand the terms **VOLTAGE DROP** and **VOLTAGE LOST**.



In diagram A, the resistor is only connected at one end and **NO CURRENT** will flow. This means the VOLTAGE DROP across the resistor will be ZERO. 12v is present on the lower lead of the resistor because no current is flowing.
In diagram B, the resistor is connected to a glowing lamp and current will flow. The voltage across the resistor may be 3v. In other words, the voltage LOST is 3v and the lamp gets only 9v. We also say the **VOLTAGE DROP** is 3v across the resistor.
In diagram C, the resistor is connected across the power rails and the voltage across it MUST be 12v. We do not talk about voltage drop or voltage lost in this circuit because there are no other components. We just say: the voltage across the resistor is 12v.

This will help you understand how a resistor works.

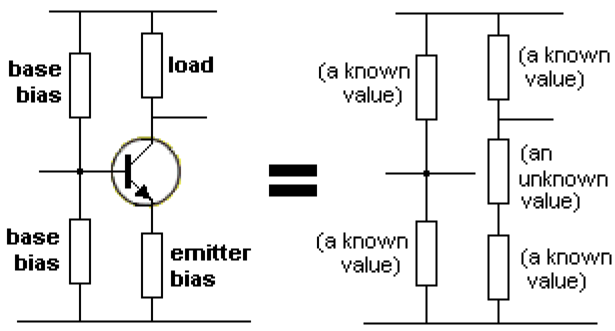
THE VOLTAGE DIVIDER

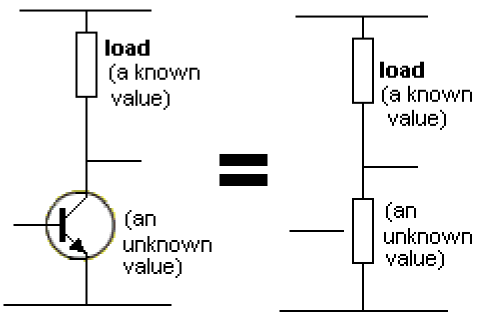
Nearly ALL circuits (and individual stages) use a VOLTAGE DIVIDER. A Voltage Divider is simply two resistors connected in series.
However it may not be two resistors. It may be a resistor and a transistor. A transistor is really a resistor - a variable resistor - and they form a voltage divider with a resistor called the LOAD.
Sometimes more resistors are present (such as resistors creating an H-bridge biasing network) and there may be more than one voltage divider in a stage.
However the same principle applies.
The principle is this:

CURRENT FLOWS THROUGH THE COMBINATION (the current is the same for each resistor because they are in series).

Multiply the current (in amps) by the resistance (in ohms) to get the voltage across each resistor.

In most cases, the sum of the voltages across each resistor must add up to the supply voltage.
Here are 2 examples of a VOLTAGE DIVIDER:





This is as far as we can go without using mathematics.

A "STAGE"

A "Stage" is a set of components with a capacitor at the input and a capacitor on the output.
We have already seen the fact that the capacitor only has an effect on the circuit during the time when it gets charged. It also has an effect when it gets discharged. But when the voltage on either lead does not rise or fall, NO CURRENT flows through the capacitor.
When a capacitor is placed between two stages, it gradually charges. When it is charged, the voltage on one stage does not affect the voltage on the next stage. That's why the capacitor is drawn as two lines with a gap. A capacitor is like putting a magnet on one side of a door and a metal sheet on the other. Moving the magnet up and down will move the metal up and down but the two items never touch.
Only a rising and falling voltage is able to pass through the capacitor.

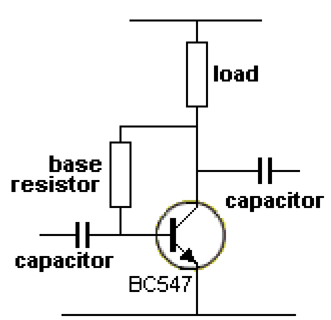


**Fig 10. This is a STAGE.
A transistor, with a capacitor on the input and output.**

Fig 10 has a capacitor on the input and output. This means the stage is separated from anything before it and anything after it as far as the DC voltages are concerned and the transistor will produce its own operating point via the base resistor and LOAD resistor. We have already explained that the value of the two resistors should be chosen so the voltage on the collector should be half-rail voltage and this is called the "idle" or "standing" or "quiescent" conditions.
It is the condition when **no signal is being processed**.
When the voltage on the collector is mid-rail, the transistor can be turned off a small amount and turned on a small amount and the voltage on the collector will fall and rise. (note the FALL and RISE).

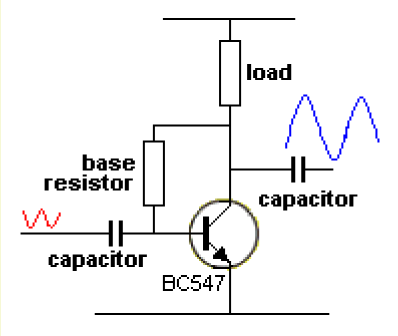


Fig 11. The Input and output waveforms

Fig 11 shows a small waveform on the input and a large waveform on the output. The increase in size is due to the **amplification** of the transistor. A stage like this will have an amplification of about 70.
This is called "**Stage Gain**" or "**Amplification factor**" and consists of two things. The output **voltage** will be higher than the input voltage and the output **current** will be higher than the input current.
We will discuss the increase in current and voltage in a moment.
We need to ask: Why is the gain of the stage only 70, when a transistor with a gain of 200 is used?
The reason is due to the base-bias resistor. It is acting as a feedback resistor and is acting **AGAINST** the incoming signal. For example, if the incoming signal is rising, the collector voltage will drop and this will be passed through the base-bias resistor to deliver less current to the base. This is opposing the current being delivered via the signal and that's why it is called NEGATIVE EFFECT or NEGATIVE FEEDBACK. Thus the transistor cannot produce the output amplitude you are expecting.

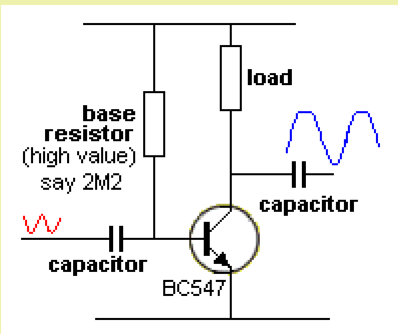


Fig 11a. Fixed Base Bias

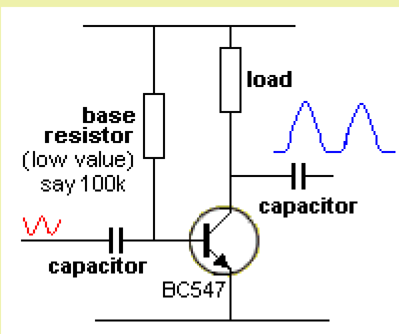


Fig 11b. Fixed Base Bias

Fig 11a and 11b shows a Common Emitter stage with fixed base-bias. This stage produces the maximum voltage amplification but it is very difficult to "set-up" because the value of the base resistor will either make the collector voltage nearly zero or full rail voltage. It is very difficult to get the collector to sit at mid rail.
If the base resistor is a high value, the collector will sit at rail voltage. If the base resistor is a low value, the collector will sit a 0v.
If a transistor with a different gain is fitted, the collector voltage will change completely.
If it sits at mid-rail, the noise produced by the transistor will make the collector voltage rise and fall and produce a lot of noise.
It all revolves around the actual gain of the transistor and this requires a TRANSISTOR TESTER to determine the gain.
However, this circuit can be used as an output stage and has some advantages.
It is a "Class-C" stage and means it is just at the point of being turned on via the base-bias resistor. It consumes the least current when "sitting around" and is the most efficient stage.
Energy from a previous stage provides base current via the coupling capacitor and the base-bias resistor assists too.
The output waveform will be distorted at the top or bottom, depending on the biasing and an inductor in the collector can reduce the distortion. See the article on FM Bugs (SPY BUGS) for a Class-C output stage.
Unless you get the biasing correct, do not use this type of stage as a general-purpose amplifier. If the transistor is saturated (the base resistor is too low) the output will consist of only the positive portions of the waveform and will be a lot smaller than a self-biased stage.

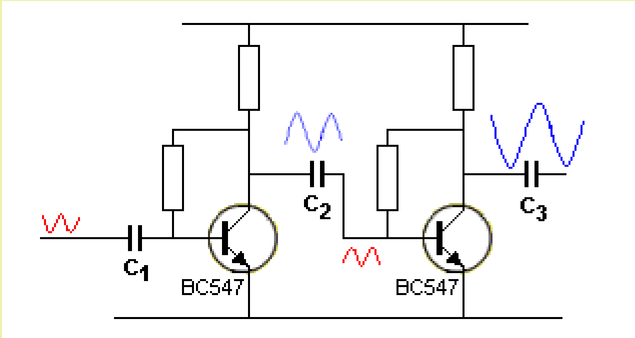


Fig 12.

Fig 12 shows the signal (the voltage waveform) as it passes through 2 stages. Note the loss in amplitude as the signal passes through capacitor C2.

CONNECTING 2 STAGES

There are 3 ways to connect two stages:
1. direct coupling - also called **DC coupling** (not the coupling shown in fig 12. **Fig 12** is AC coupling). DC stands for Direct Current. I know this sounds unusual, but it is the way to explain the circuit will pass (amplify) DC voltages. This type of coupling will pass both AC signals and DC voltages. When the DC voltage moves up and down (even at a slow rate) we call it an AC voltage or AC signal or a rising and falling voltage and when it rises and falls faster, we call it a "signal" or waveform.
2. via a capacitor - this is also called **RC coupling** (Resistor-Capacitor coupling) - only passes AC signals - fluctuating signals - rising and falling signals.
3. via a transformer - called **Transformer Coupling** or Impedance Coupling or Impedance Matching - only passes AC signals.

Fig 12 shows two stages with a capacitor coupling the output of the first to the input of the second. This is called **Capacitor Coupling** or **Resistor-Capacitor Coupling** (**RC Coupling**).
The increase in the size of the waveform at three points in the circuit is also shown.
The waveform is inverted as it passes through each transistor and this simply means a rising voltage will appear as a falling voltage and after two inversions, the output is **in-phase** with the input.
We have already explained the fact that a capacitor only works **once** and has to be discharged before it works again. When the first transistor turns off a little, the voltage on the collector rises and the resistor pulls the left lead of C_2 UP. The right-hand lead can only rise to 0.7v as the base-emitter voltage does not rise above 0.7v. This means C_2 charges and during its charging, it delivers current to the second transistor.
When the first transistor turns ON, the collector voltage drops and C_2 passes this voltage-drop to the base of the second transistor. But the transistor does not provide a path to discharge the capacitor fully so that when the capacitor gets charged again, it is already partially charged and it cannot activate the base of the second transistor to the same extent as the first cycle.
This means a lot of the energy available at the collector of the first transistor is not delivered to the second stage. That's why capacitors produce losses between stages. They are simply an inefficient way to transfer energy. To make them efficient, they must be discharged fully during the "discharge-part" of the cycle.
However enough is delivered to produce a gain in the second stage to get an overall gain of about 70 x 70 for the two stages.
The value of C_2 will be from 10n to 10u, and the larger capacitance will allow low frequencies to be passed from one stage to the other.

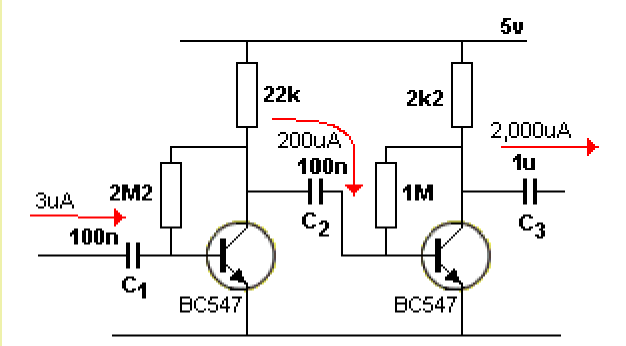


Fig 13.

Fig 13 provides a guide to the values of current that will be flowing at 3 important sections of the circuit.
The input current to operate the first transistor will be about 3uA. This is worked out on the basis of the current required to saturate the transistor with a 22k load. The collector-emitter current equals 5/22,000 = 200uA. If the gain of the transistor is 70, the input current is 3uA.
The only time when energy passes from the first stage to the second is when transistor turns OFF. The collector voltage rises and the 22k pull the 100n HIGH.
The maximum current that can be delivered by the 22k is 5v/22,000= 200uA. This is the absolute maximum for a very small portion of the cycle. However it is important to realise it is not the transistor that passes the current to the next stage but the load resistor.
The gain of the second stage is not the deciding factor for the output current but the value of the 2k2 load resistor. This resistor will deliver a maximum of 2,000uA (2mA) and that is how a 3uA requirement at the input of the circuit will deliver 2mA at the output.

You can see it is not the gain of the transistors that produce the output current but the value of the load resistors. The transistors play a part but the limiting factor is the load resistors (and the transfer of energy via the capacitor). This is not always the case but applies in the above circuit.

We will now explain an emitter-follower stage and show how it works.
An EMITTER-FOLLOWER is an NPN transistor with the collector connected to the positive rail. (You can also get PNP EMITTER-FOLLOWER stages - see below). Both can be called a COMMON COLLECTOR stage.

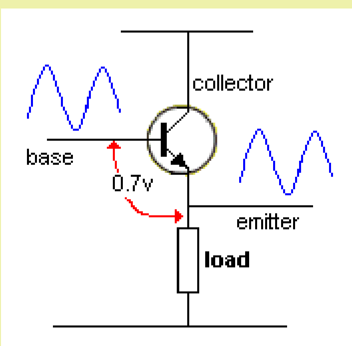


Fig 14. An Emitter-Follower or Common Collector. The names are the SAME

Fig 14 shows an Emitter-Follower.
The load is in the emitter and as the base is taken higher, the emitter follows. But the input and output voltage signals are the SAME amplitude!
You would ask: "What is the advantage of this?"
Answer: You only need a small amount of "lifting power" to raise the base and the emitter rises with 100 times more strength. The voltage waveform stays the same but the CURRENT waveform increases 100 times.
The voltage on the emitter is always 0.7v lower than the base and the base can be as low as 0.8v and as high as 0.5v less than the supply voltage. This gives the possibilities of producing an enormous "swing."
In the **common-emitter stage** the transistor is only active when the base rises from 0.55v to about 0.7v but in the **Emitter-Follower** stage it rises from 0.8v to nearly rail voltage.
This means the stage does not produce a higher output voltage but it does produce a higher output **CURRENT**.
We mentioned before the current amplification of a stage was not dependent on the transistor characteristics but the value of the load resistor. In an **Emitter-Follower** stage we can quite easily get a current gain of 100 or more.
Why do we want "Current Gain?" We need **current** to drive a

low resistance load such as a speaker.

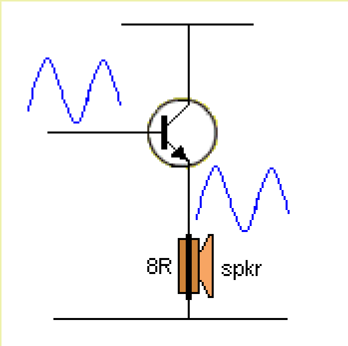


Fig 15. A transistor driving a speaker

Fig 15 shows an 8 ohm speaker as the load in the emitter. If the gain of the transistor is 100, the 8R speaker becomes 8x100 = 800 ohms on the base lead. In other words we see the circuit as "800 ohms."

See this link for the answer to a constructor. He wanted to increase the output from his mobile handset.

1. For an emitter-follower circuit, we know the base can rise and fall by an amount equal to about rail voltage.
2. For a common-emitter stage the collector rises and falls by an amount equal to rail voltage.
So, why not connect the two stages together without a capacitor?
We know a capacitor has considerable losses in transferring energy from one stage to another and removing it will improve the transfer of energy.

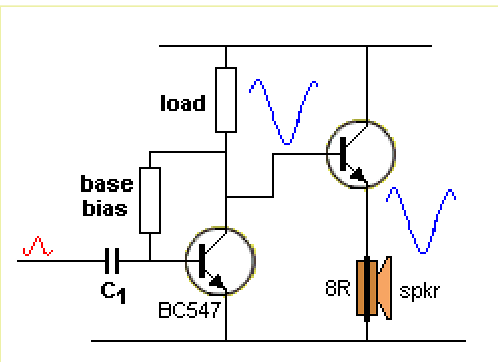


Fig 16. Two directly coupled stages

Fig 16. We now have two stages directly connected together.
The first transistor does not deliver energy to the second stage but the **LOAD RESISTOR** does.
The value of the load resistor pulls the base of the second transistor UP and this delivers current to the second transistor and the transistor amplifies this 100 times to drive the speaker.

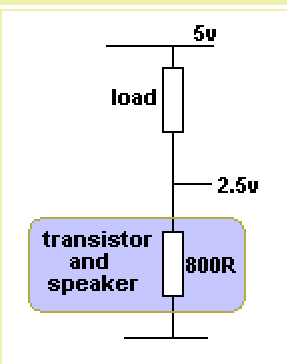


Fig 17. The load resistor and the effective load of the speaker

Fig 17. Using mathematics we can work out the effective load of the 8 ohm speaker as 8 x 100 = 800 ohms. To put at least half rail voltage into the speaker, (so the speaker can get the maximum higher voltage and the maximum lower voltage without distorting) the LOAD resistor has to be the same value as the "emitter follower."
This is a simple voltage-divider calculation where two equal value resistors produce a voltage of 50% at their mid-point.

This means the LOAD resistor for the first stage has to be 800 ohms.

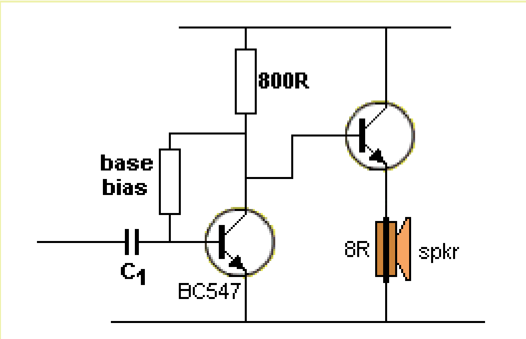


Fig 18. The load resistor is 800 ohms

Fig 18 shows the circuit with 800R load resistor in the collector of the first transistor.
The final requirement is to select a base-bias resistor for the first stage to produce approx mid-rail voltage on the collector.
This is generally done by experimentation.

8R SPEAKER Vs 50R SPEAKER

Most of the speakers used in transistor radios have an impedance (resistance) of 8R for the VOICE COIL. This has been chosen because it is very easy and cheap to produce. The wire in the coil is also quite thick and robust.
But it is interesting to note that speakers with a high resistance voice coil will produce an equal volume and require less driving current. This applies to 33R speakers as well as 50R speakers.
The reason is this:
Moving the cone requires a certain amount of flux and this can be produced by a small number of turns and a high current or a large number of turns and a low current.
The flux is a product of turns x current and this is called AMP-TURNS. In other words, AMPS x TURNS.
If you find a 33R or 50R speaker in a kit, you will know it will perform just as loud as an 8R speaker.

We mentioned the capacitor separating two stages cannot be discharged fully and thus it does not provide very good transfer of energy from one stage to the other.
An improved concept is to directly couple two stages - and remove the coupling capacitor.
This is called DIRECT COUPLING or DC coupling and the circuit will process DC voltages (the press of your finger as shown above) and AC voltages (as shown by the sine-wave signal shown above).
When a capacitor connects two stages they will only amplify AC signals.

There are many ways to directly connect two transistors and we will cover the simplest arrangement. It is an extension of Fig 18 above, because this arrangement has very good characteristics as the two stages transfer 100% of the energy due to the absence of a capacitor.

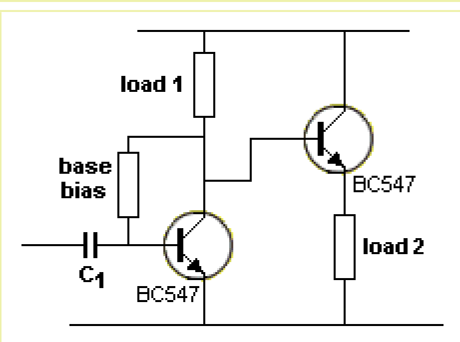


Fig 19.

Fig 19 shows the previous directly-coupled circuit with a load resistor replacing the speaker.
We have already learnt the common-emitter stage provides a voltage gain of about 70 but the emitter-follower stage has a voltage gain of only 1. We can improve this by putting two resistors on the second transistor and changing the stage into a common emitter arrangement.

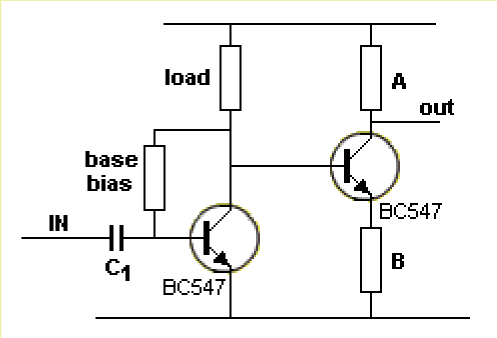


Fig 20.

Fig 20. This time we get the advantage of the base being able to move up and down so it matches the collector of the first transistor. It also provides a higher voltage gain by adding a collector resistor and taking the output from the collector. The voltage gain of the second transistor will not be as high as the first stage but we have added the advantage of direct coupling (called DC coupling).
The voltage gain of the second stage is the ratio of resistor A divided by resistor B. If resistor A is 10k and resistor B is 1k, the voltage gain is 10,000/1,000 = 10.

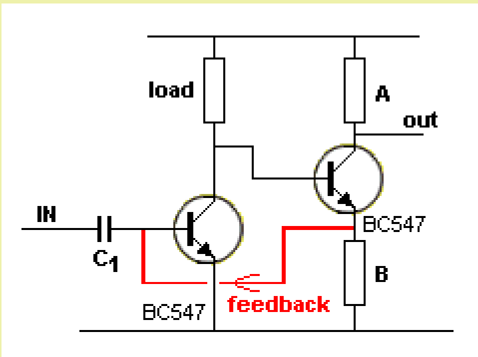


Fig 21.

Fig 21 shows biasing of the first transistor has been taken from the emitter of the second transistor. This does not save any components but introduces a new term: **FEEDBACK** (actually **NEGATIVE FEEDBACK**).
Negative feedback provides stability to a circuit. Transistors have a very wide range of values (called parameters) such as **gain** and when two transistors are placed in a circuit, the gain of each transistor can produce an enormous final result when the two values are multiplied together.
To **control this** we can directly couple two transistors and take the output of the second to the input of the first.

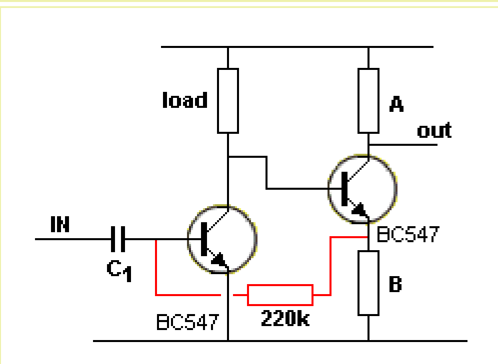


Fig 22.

Fig 22. When the voltage on the base of the first transistor rises, the voltage on the collector drops and this is transferred to the second transistor. The voltage on the emitter of the second transistor drops and this is fed back to the base of the first transistor to oppose the rise. Obviously this arrangement will not work as the voltage being fed back is HIGHER than the signal we are inputting, but if we add a 220k resistor we can force against the feedback signal and produce an output.

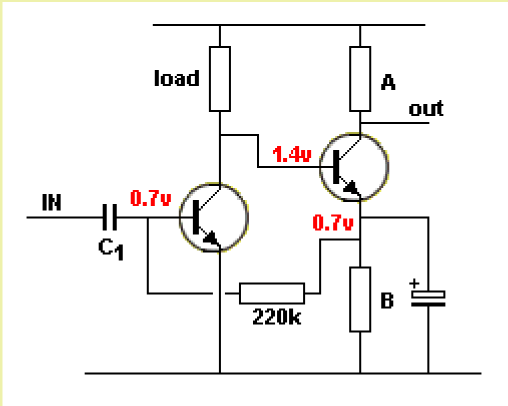


Fig 23.

Fig 23. We have added a capacitor (electrolytic) to the emitter of the second transistor. Let's explain how this electrolytic works.
An electrolytic is like a miniature rechargeable battery.
It charges very slowly because it is a large value.
Initially it has 0v.
The circuit starts to turn ON by current flowing through the load resistor and this turns on the second transistor. (The first transistor is not turned on AT ALL at the moment). The base rises and pulls the emitter up too. And when the emitter is about 0.7v, this voltage is passed to the first transistor via the 220k and the first transistor starts to turn on. This causes current to flow through the collector-emitter leads and pulls the voltage on the base of the second transistor down to about 1.4v

This is how the two transistors settle, with the voltages shown in Fig 23.
The electrolytic has 0.7v on it and when a signal is delivered to the base of the first transistor, it is amplified and passed to the emitter of the second transistor. Normally the emitter would rise and fall as explained in the above circuits and the result would be heard in the speaker. But the electrolytic takes a long time to charge (and discharge) and it resists the rise and fall of the signal.
This means the signal cannot rise and fall at the emitter.
In other words we have placed the second transistor in a stage very similar to the first stage we described a **COMMON EMITTER**.
Since the emitter voltage does not rise and fall, it does not pass a signal through the 220k to the base of the first transistor. This means our input signal is not fighting against the feedback signal and it has a larger effect on controlling the first transistor. This gives the first transistor a bigger gain.
A common emitter stage has a voltage gain of about 70-100 and we now have one of the best designs. Two common-emitter stages, directly-coupled (DC) and with very HIGH GAIN. The feedback only controls the DC voltages on the two transistors and does not have an effect on the AC (signals).

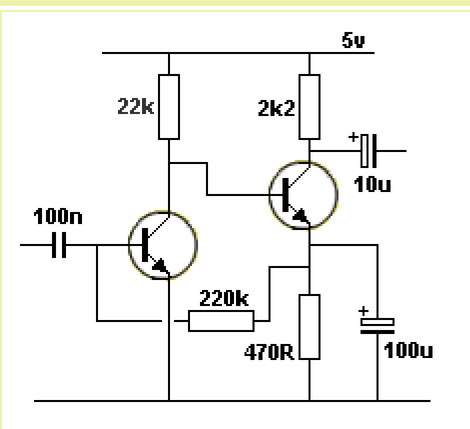


Fig 24.

Fig 24 shows typical values for biasing the two transistors.
This circuit has been tested with a speaker as the input device. It produces 2mV with a whistle at 30cm and the output produced a sinewave of 3,000mV (a gain of 1,500)
The component values are show in Fig 24a:

Fig 24a is the best circuit you can get for amplifying a signal. The two

transistors are biased via the 470k feedback resistor so they are turned ON and ready to amplify the signal. There is no capacitor between the two transistors so the overall gain is very high.

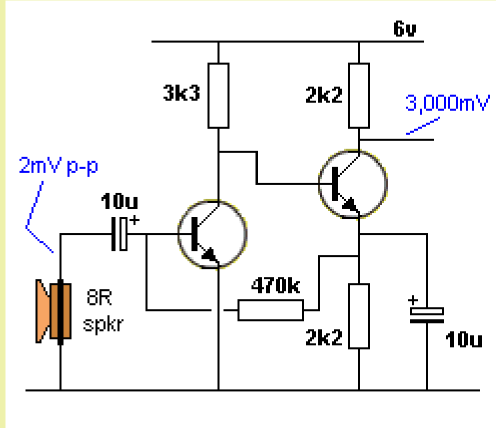


Fig 24a - the best circuit you can get.

This circuit is also called a **WIDEBAND AMPLIFIER** because it will amplify all frequencies.

From what you have learnt, you can see the mistakes and/or the voltages in the following circuit:

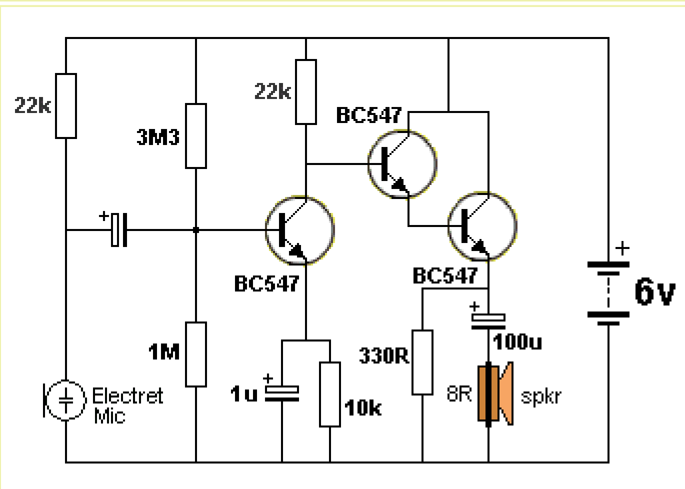


Fig 25.

Fig 25. The two joined transistors create a Darlington transistor and this is just a normal transistor with a large gain.
The 330R discharges the 100u and it will only discharge it a very small amount. This means the electro can only be charged a very small amount during the next cycle and the output will be very weak.
It is the 330R that determines how much (little) energy gets delivered to the speaker. The 330R has to be 15R to nearly fully discharge the 100u.

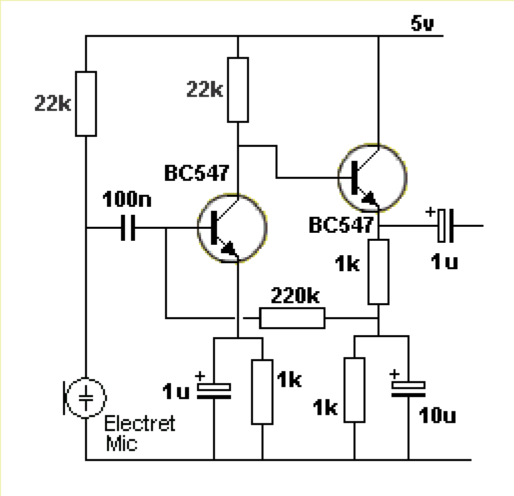


Fig 26.

Fig 26. You can work out the voltage on the various points in this circuit by referring to the examples we have already covered.

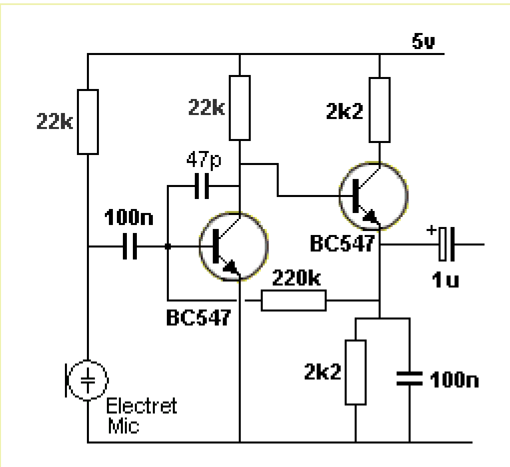


Fig 27.

Fig 27. This is a practical example of the circuit we have discussed. It is a **MICROPHONE AMPLIFIER** (also called a pre-amplifier stage).

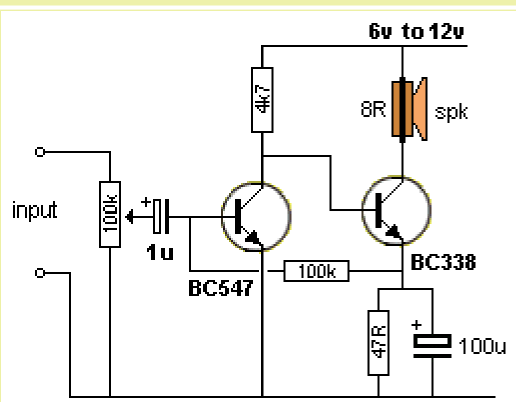


Fig 27a.

Fig 27a. Here is the same circuit used as a **POWER AMPLIFIER**.
Both transistors are common-emitter configurations and the circuit produces high gain due to the DC (direct) coupling.

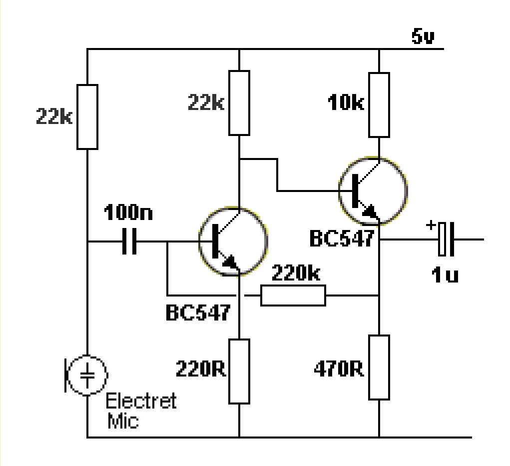


Fig 27b.

Fig 27b. You can create a circuit with a FIXED GAIN by selecting values for the gain of each stage. This is calculated by dividing the collector resistor by the the emitter resistor.
For the first stage, the gain is 22,000/220 = 100. The gain of the second stage is 10,000/470 = 20. The gain for the two stages is 100 x 20 = 2,000. See **Stage Gain** for more details.

The POWER of a SIGNAL

Before we go too much further, we need to talk about the POWER OF A SIGNAL.
What is a SIGNAL?
A Signal is a voltage produced by a microphone, an inductor, or the output from a previous stage.
It may be the signal for the "input" of the amplifier in **Fig 27a** above, or it may be the resistance of your finger in the circuits above, or it may be the signal from a single stage shown above (as a sinewave).
A signal may be an audio waveform with a very small amplitude or a DC voltage from a switch or a digital signal from a chip or the output from one of the stages shown above.
In all these instances we have described the amplitude of a signal. The amplitude is the VOLTAGE of the signal.
But a signal consists of a VOLTAGE and comes with a value of CURRENT. This current may be very small (such as from an electret microphone) or it may be very high (such as from a switch).
In most cases we do not talk about the value of current associated with the signal. Mainly because it is a very complex problem, matching-up the "current-capability" of the signal with the "current requirement" of the following stage.
At this point we will simply say that ALL signals come with a VALUE OF CURRENT. And this is called "The Power of a SIGNAL." In other words: The STRENGTH of a Signal" or the "Driving capability of a signal.
We can also say a signal is "very weak" or "delicate" or "strong" or "has good driving capability."
Some signals will drive a LED or speaker while others need to be amplified before they can be used.
In most cases the "driving power of a signal" is unknown. It is not provided as a specification. And yet its value is MOST IMPORTANT. In most cases you cannot work out the current-capability of a signal by looking at the device generating the signal. For instance, if the signal comes from a magnetic pick-up coil, or the output of a pre-amplifier where the circuit is not provided.
That's why the matching of a signal to an input circuit is so complex and is a topic for an advanced section of a discussion.
In the meantime we will assume the signal and the input of the stage it is driving, has the appropriate input impedance so the signal is not attenuated (reduced) too much.
If a signal has a high current it can be connected to a high or low impedance input and the amplitude will not be affected.
If a signal with very little current is connected to the input of an amplifier and the input has a low impedance, the amplitude of the signal will be reduced. That's why the input needs to be as high as possible.
Maximum POWER is delivered from one stage to the next when the impedance of the source matches the impedance of the load.
Maximum VOLTAGE is delivered from one stage to the next when the impedance of the source is LOW and the impedance of the load is HIGH.

USING PNP TRANSISTORS

A PNP transistor can be used in the 2-Transistor DC amplifier studied above. It does not produce a higher gain or change the output features of the circuit in any way but you may see an NPN and PNP

used in this configuration and need to know how they work.
Firstly we will discus how a PNP transistor works. All those things you learnt in the first set of diagrams can be repeated with a PNP transistor. The circuits are just a mirror-image of each other and the transistor is simply "turned-over" and connected to the supply rail.
Study the following circuits to understand how a PNP transistor is TURNED ON.

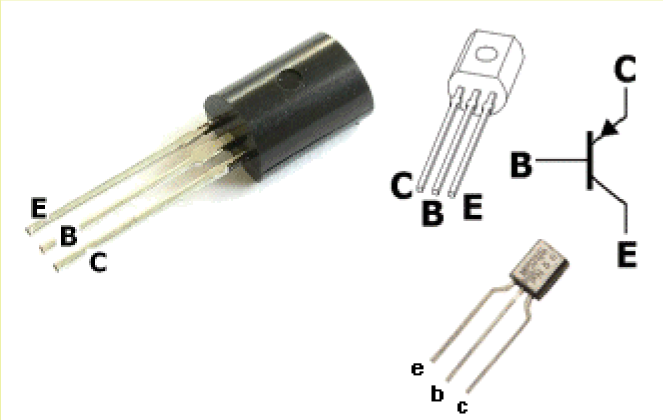


Fig 28. PNP Transistor Symbol

Fig 28. The symbol for a PNP transistor has the arrow pointing towards the BASE.

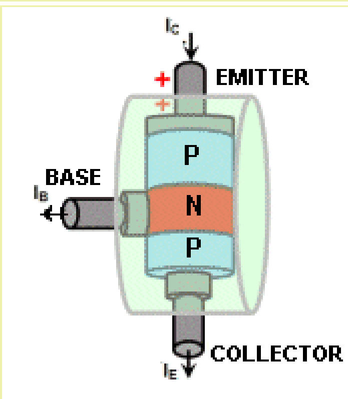


Fig 29. PNP "Water Valve"

Fig 29 shows the equivalent of a PNP transistor as a water valve. As more current (water) is released from the base, more water flows from the emitter to the collector. When no water exits the base, no water flows through the emitter-collector.

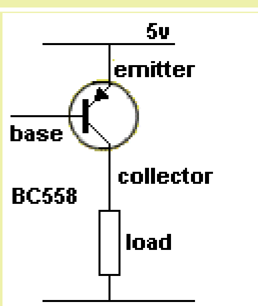


Fig 30. PNP connected to the power rails

Fig 30 shows a PNP transistor with the emitter lead connected to the power rail. The collector connects to a resistor called a LOAD RESISTOR and the other end connects to the 0v rail or "earth" or "ground."
The input is the base and the output is the collector.

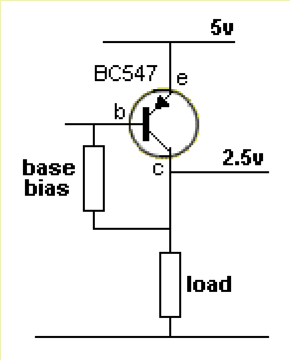


Fig 31. PNP Transistor biased with a "base bias" resistor and a LOAD resistor

Fig 31 shows a PNP transistor in SELF BIAS mode. This is called a COMMON EMITTER stage and the resistance of the BASE BIAS RESISTOR is selected so the voltage on the collector is half-rail voltage. In this case it is 2.5v.
Here's how you do it. Use 22k as the load resistance.
Select the base bias resistor until the measured voltage on the collector is 2.5v. The base bias resistor will be about 2M2.
This is how the transistor gets turned on by the base bias resistor:
The base bias resistor allows a small current to pass from the emitter to the base and this makes the transistor turn on and create a current-flow though the emitter-collector leads.
This causes the same current to flow through the load resistor and a voltage-drop is created across this resistor. This raises the voltage on the collector.
This causes a lower current to flow from the emitter to the base, via the base-bias resistor, and the transistor stops turning on a slight amount.
The transistor very quickly settles down to allowing a certain current to flow through the emitter-collector and produces a voltage at the collector that is just sufficient to allow the right amount of current to flow from the base. That's why it is called SELF BIAS.

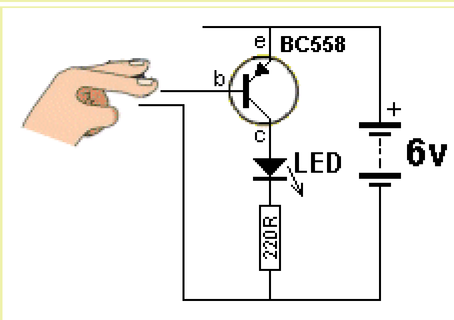


Fig 32. Turning ON an PNP transistor

Fig 32 shows the transistor being turned on via a finger. Press hard on the two wires and the LED will illuminate brighter. As you press harder, the resistance of your finger decreases. This allows more current to flow from the emitter to the base and the transistor turns on harder.

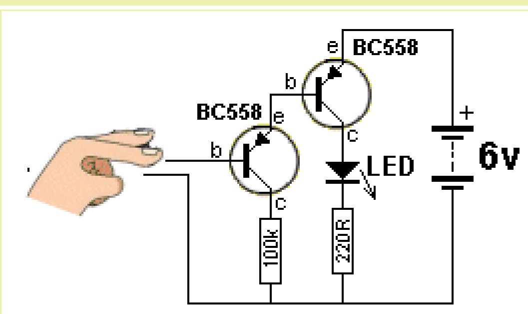


Fig 33. Two transistors turning ON

Fig 33 shows a second transistor to "amplify the effect of your finger" and the LED illuminates about 100 times brighter.

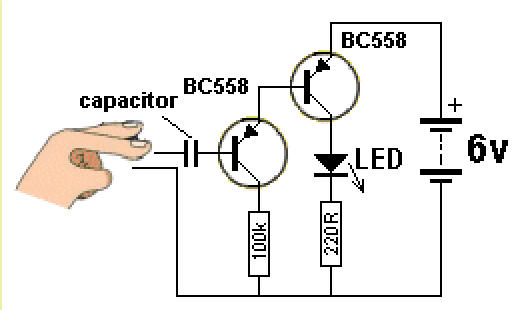


Fig 34. Adding a capacitor

Fig 34 shows the effect of putting a capacitor on the base lead. The capacitor must be uncharged and when you apply pressure, the LED will flash brightly then go off. This is because the capacitor gets charged when you touch the wires. As soon as it is charged, NO MORE CURRENT flows though it. The first transistor stops receiving current and the circuit does not keep the LED illuminated. To get the circuit to work again, the capacitor must be discharged. A large-value capacitor will keep the LED illuminated for a longer period of time as it will take longer to charge

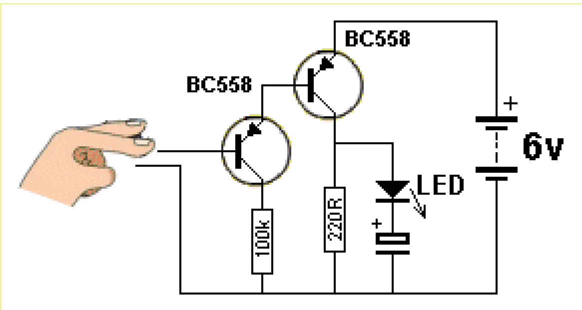


Fig 35. Adding a capacitor to the output

Fig 35 shows the effect of putting a capacitor on the output. It must be uncharged for this effect to work. We know from Fig 33 that the circuit will stay on constantly when the wires are touched but when a capacitor is placed in the OUTPUT, it gets charged when the circuit turns ON and only allows the LED to flash.

THE NPN/PNP AMPLIFIER

A 2-Transistor DC amplifier can be constructed using an NPN and PNP set of transistors.

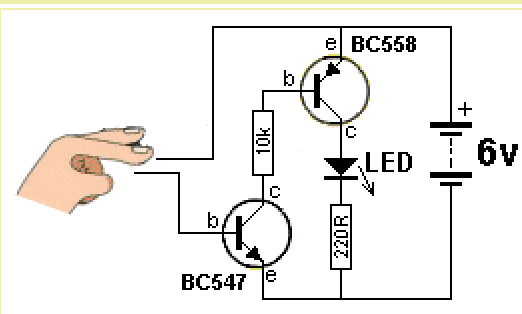


Fig 36.

Fig 36 shows how an NPN-PNP set of transistor is turned on.
You can think of the "turning ON" this way:
The base of the NPN get "Pulled UP" and the base of the PNP gets "Pulled DOWN."
It does not matter how you refer to the operation of the circuit, you must be able to "**SEE**" how the circuit works so you can **see** a more-complex circuit working too!

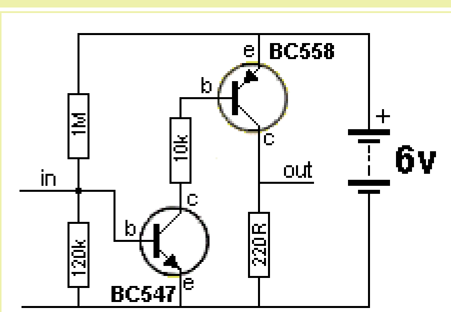


Fig 37 shows biasing on the base of the first transistor and the "in" and "out" leads have been identified.
This circuit has a very high gain and if "general purpose" transistors are used with a very high spread of gain for each transistor, the result will be a very wide range of voltages on the output terminal. If each transistor has a gain of 100, a change of 1mV on the input will result is a voltage change of 0.001 x 100 x 100 = 10v. We don't have a 10v supply so, this type of circuit is very UNSTABLE!
We need to design a circuit that has FEEDBACK so the

Fig 37.

output voltage will remain within the voltage of the supply. This feedback is called NEGATIVE FEEDBACK as it opposes an input signal to provide correction or stability. Later we will talk about POSITIVE FEEDBACK and show what an amazing difference it creates - the circuit behaves totally differently.

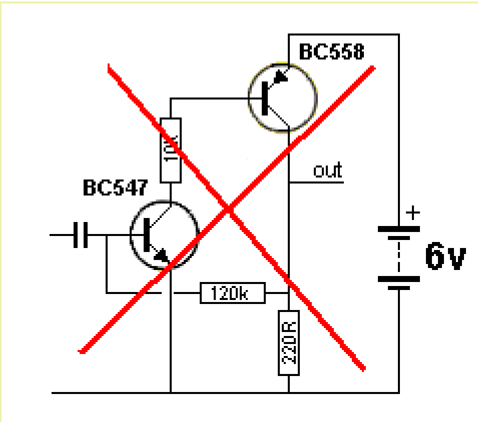


Fig 38. This circuit does not work

Fig 38 will not work because the base of the NPN transistor is not turned on when the circuit is switched on.
This is one of the things you have to look for when designing a circuit.

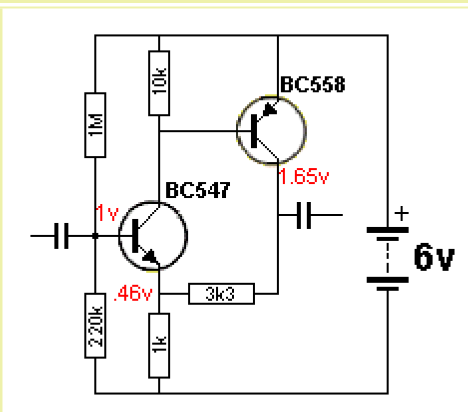


Fig 39. The voltages

Fig 39 has a voltage-divider network on the base of the NPN transistor. It turns the first transistor ON and this turns the PNP transistor ON until the voltage at the join of the 3k3 and 1k puts a voltage on the emitter of the first transistor to start turning it OFF.
This is a point we have to explain.
There are two ways to turn ON an NPN transistor.
1. Hold the emitter fixed and RAISE the base voltage.
2. Hold the base fixed and LOWER the emitter voltage.

In **Fig 39** the base is weakly fixed by the voltage divider made up of the 1M and 220k and even though the base can move up and down a little bit, we will assume the voltage is constant. If we raise the emitter voltage, the transistor will be turned off. This is what the FEEDBACK voltage via the 3k3 does. It raises the emitter voltage and turns the NPN transistor OFF slightly so an equilibrium point is reached where the two transistors are turned on a small amount and if one gets turned on a little more, the other sends signal to turn it OFF. This is not a practical circuit as an increase of 1mV on the input will produce a large change on the output and this will be reflected back to the emitter of the first transistor to cancel the input voltage.

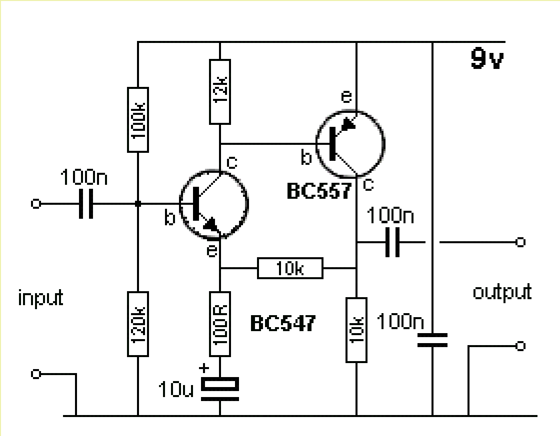


Fig 40. A practical example

Fig 40. By changing the value of the feedback resistors we get Fig 40. The values are now 10k and 100R.
This gives a ratio of 10,000:100 or 100:1 and it means the output can rise 100mV before the emitter gets 1mv to cancel the input voltage. This means the amplifier will have a gain less than 100 but provides a very stable set of voltages.

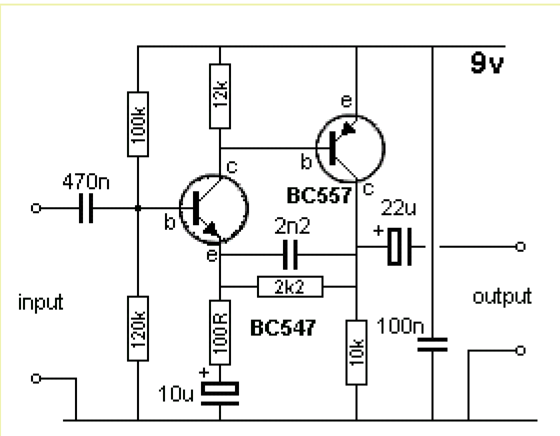
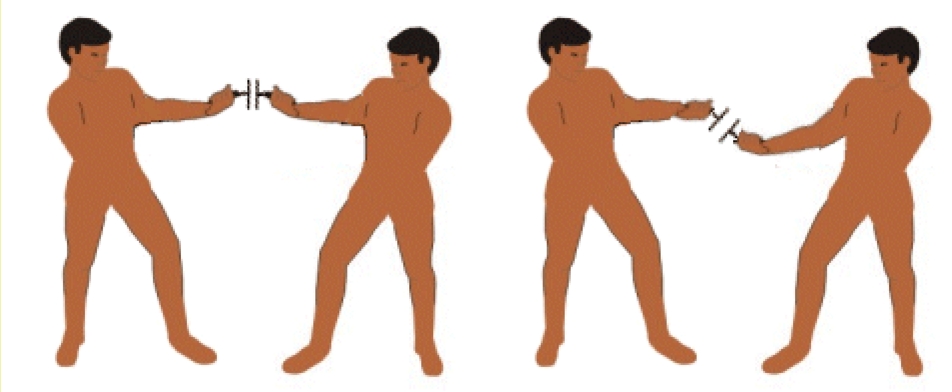


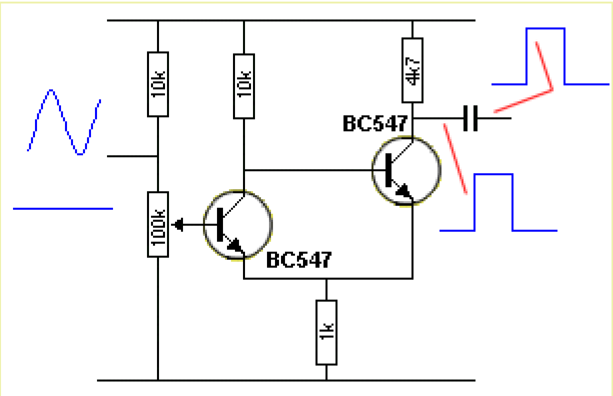
Fig 40a. Another practical example

Fig 40a. Here is an amplifier with the same DC biasing as Fig 40 but with a lower overall gain (2,200:100 or 22:1) and high-frequency feedback (attenuation) via the 2n2 capacitor.

The CAPACITOR

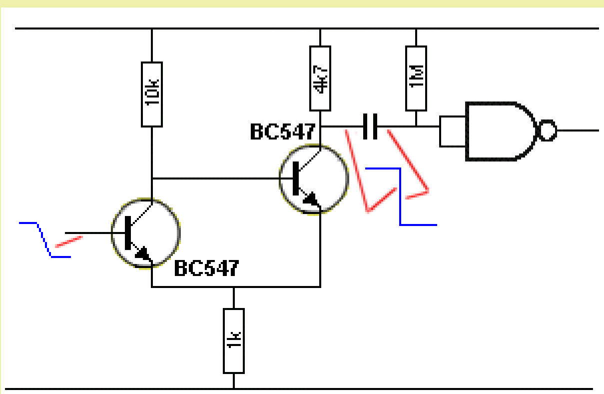
The capacitor is a very complex item to discuss because it performs so many different effects, depending on its value and where it is placed in a circuit.
However one of the most important concepts is to see that a signal on the left side will pass through the capacitor and appear on the other side with about the same amplitude, if the signal is fast-acting. In other words: high-frequency. This is shown in the first animation where the movement of the first person is transferred directly to the second person.
If the signal has a low-frequency, is will get charged and discharged during the cycle and the amplitude on the output will be small. This is shown in the second animation where the capacitor is charging and discharging and the second person is seeing a small effect.





The circuit shows a Schmitt Trigger arrangement. This is covered HERE.
The Schmitt Trigger is **FAST ACTING** and this means the signal on the left-plate of the capacitor will be delivered to the output of the circuit.
Delivering 100% of the amplitude will depend on:
1. The value of the capacitor,
2. The rise-time of the signal and
3. The load on the right-plate of the capacitor.
At the moment we just need to VISUALISE the way the capacitor will work.

The capacitor will pass a "spike" or "signal" from one stage to another:



The capacitor sending (transferring) a PULSE to the DIGITAL GATE. This is a VERY IMPORTANT concept.

The capacitor in the diagram is transferring the "drop in voltage" on the left-plate to the right-plate.
The voltage on the input to the **DIGITAL NAND GATE** is initially rail voltage and it must drop to less than 30% of rail voltage for the gate to see a LOW.
The value of the capacitor is chosen so this will occur.
When the voltage on the left-plate drops, the capacitor will begin to charge via the 1M resistor and the circuit-designer must make sure the charging of the capacitor will be very small during the time when the voltage drops so the right-plate will send a 30% rail voltage to the gate. If the value of the capacitor is too small, it will get charged very quickly and the right-plate will only drop a small percentage of rail-voltage.

MEASURING THE VOLTAGE(S)

The voltage on each line (connection) of a circuit can be measured with a multimeter. To help you take (make) a reading, we have written an eBook titled: **Testing Electronic Components**. There is a certain amount of skill required to take a reading and this eBook will help you enormously**.**

OSCILLATORS

If we remove some of the components from Fig 39 and put a LED on the emitter of the PNP transistor we have a circuit that will illuminate the LED.
We have already talked about FEEDBACK in terns of NEGATIVE FEEDBACK to stabilize a circuit.
We will now cover a new term called **POSITIVE FEEDBACK** - it changes the performance of circuit completely. It makes the circuit OSCILLATE. Negative feedback "kills" a circuits performance - positive feedback makes it oscillate. It increases the signal so much that the circuit becomes

unstable. This is called oscillation.

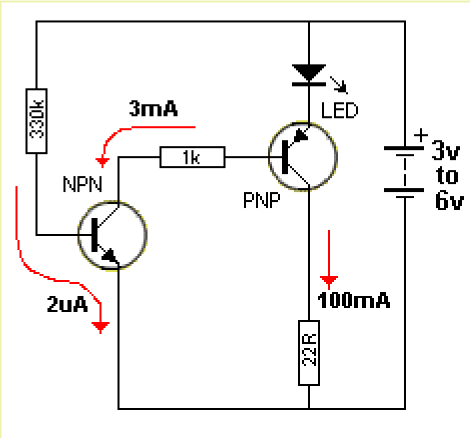


Fig 41.

Fig 41 shows a circuit using an NPN and PNP connected via a 1k resistor and turned ON via a 330k base resistor. The LED will illuminate.
There is nothing magic about this circuit. It is simply a HIGH-GAIN, DC-AMPLIFIER using two transistors.
The values of current are only approximate and show how each section allows an increasing amount of current to flow.
A current of 100mA is too high for a LED and it will be damaged. This circuit demonstrates the possible current-flow. If this current flows for a very short period of time, the LED will not be damaged. Fig 42 shows how the circuit is converted to an oscillator or "flasher."

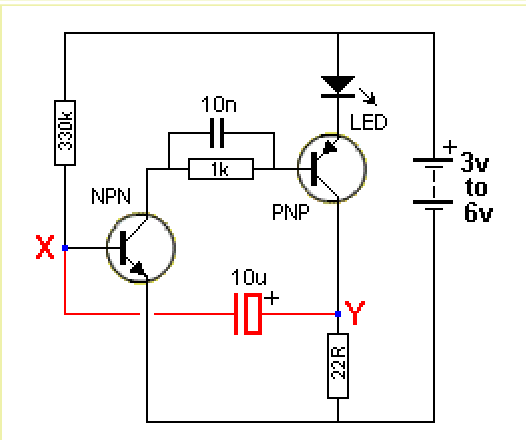


Fig 42.

Fig 42. When we connect a capacitor as shown, an amazing thing happens. The high-gain amplifier turns into an OSCILLATOR. When the voltage on point "X" is rising, the voltage on point "Y" is rising TOO. But point "Y" rises much higher than point "X."
This means that if we DIRECTLY join points X and Y, the voltage-rise from point Y will push point X higher and turn the circuit ON more. This will continue until the circuit is fully turned ON and the two transistors are SATURATED.

This effect is called POSITIVE FEEDBACK and the circuit will get turned ON until it cannot turn on any more.
But we haven't joined points "X" and "Y" DIRECTLY (we have used a capacitor) so we have to start again and explain how the circuit works.
When the power is applied, the 10u gradually charges and allows a voltage to develop on the base of the NPN transistor. When the voltage reaches 0.6v, the transistor turns ON and this turns on the PNP transistor.
The voltage on the collector of the PNP transistor increases and this raises the right side of the 10u electrolytic and it firstly pushes its charge into the base of the NPN transistor. Then the 330k takes over then it continues to charge in the opposite direction via the base-emitter junction of the NPN transistor. This causes the two transistors to turn ON more. This keeps happening until both transistors cannot turn ON any more and the 10u keeps charging. But as it continues to charge, the charging current eventually drops slightly and this turns off the first transistor slightly. This gets passed to the PNP transistor and it also turns off slightly. This instantly lowers both leads of the 10u and both transistors turn OFF.
The 10u is partially charged and it gets discharged over a long period of time by the 330k resistor and when it starts to charge in the opposite direction, the base of the first transistor sees 0.6v and the cycle starts again.

The end result is a very brief flash and a very long pause (while the capacitor starts to charge again).
As you can see, there is very little difference between the high-gain DC amplifier we discussed above and the oscillator circuit just described.
That's why you have to be very careful when looking at a circuit, to make sure you are identifying it correctly.

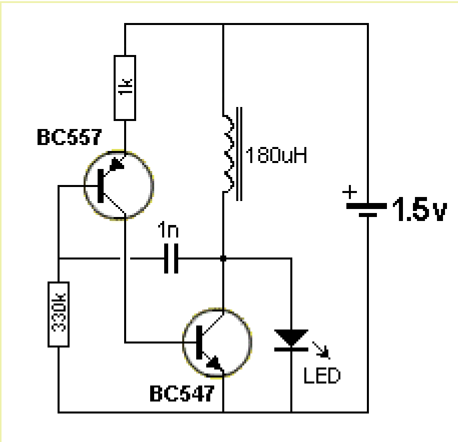


Fig 43.

Fig 43 is the same circuit with the components re-arranged. It is a high-frequency oscillator with an inductor as the load and when the circuit turns off, the inductor produces a high voltage in the opposite direction to the supply voltage and this is high enough to illuminate a LED. The LED will not illuminate on the 1.5v supply so when the LED illuminates, you know the circuit is working.

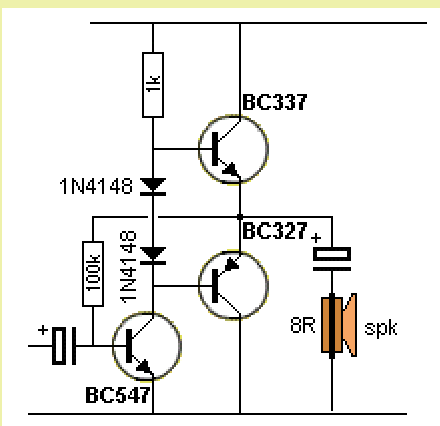


Fig 44.

Fig 44 is the same arrangement of the two transistors we have just studied, but with a third transistor above the two.
We have already seen the importance of charging a capacitor (and then it must be discharged so that the re-charge will produce a "current-flow.")
That's what the two transistors in the output are doing.
The top transistor charges the electrolytic and the bottom transistor discharges it.
In the process, the charging and discharging current flows through the speaker to produce audio.
We have already studied the two lower transistors. The BC327 turns ON and allows current to pass through the emitter-collector leads and this discharges the electrolytic.

The top transistor is an emitter-follower and it turns ON when the bottom two transistors are effectively "out of circuit."
The base is pulled to the supply rail by the 1k and the emitter follows. In other words the collector-emitter leads allow current to flow and this charges the electrolytic. The charging current flows through the speaker.

CURRENT GAIN OF AN EMITTER FOLLOWER STAGE

We have seen the need to provide current into and out of a speaker to move the cone. This is because current produces magnetic flux and many items work on magnetic flux, such as: motors, relays and speakers. And some items need a lot of current to be activated - especially globes.
Most transistors will provide a CURRENT GAIN of 100 when up to 25% of their rated current flows, but only a gain of 50 for the next 25% increase in current and a gain of 30 for the next 25% increase in current and a gain of only about 10 when the maximum allowable current flows.

That's why you have to understand transistor data-sheets. The gain of a transistor is very low when maximum current flows.
There is a hidden factor with motors and globes. They take 6 TIMES more current for a globe to start glowing or to start a motor revolving. This is because the resistance of a cold globe is only one sixth of its glowing resistance and a motor has a very low resistance until the back emf (electro-motive force - another name for voltage) produced by the armature, reduces the current-flow.
This means you have to design a circuit that will deliver up to 6 times the operating current, so these items will turn on.
We explained the 800R LOAD resistor provides the turn-on current for the speaker in the following circuit. When the BC547 turns off, the current through the 800R is amplified by the emitter-follower transistor to drive the speaker. This is a very wasteful way of operating a circuit as current is always flowing through the 800R and during part of the cycle, this current is not achieving any result.
We can design a circuit where this current is provided by a transistor.
This is important when we are providing high currents as a transistor can be turned on to deliver the current and turned off when the current is not required,. This saves energy and prevents over-heating.
We will look at the following 2-Transistor DC amplifier driving a speaker (taken from Fig 18) and modify the circuit.

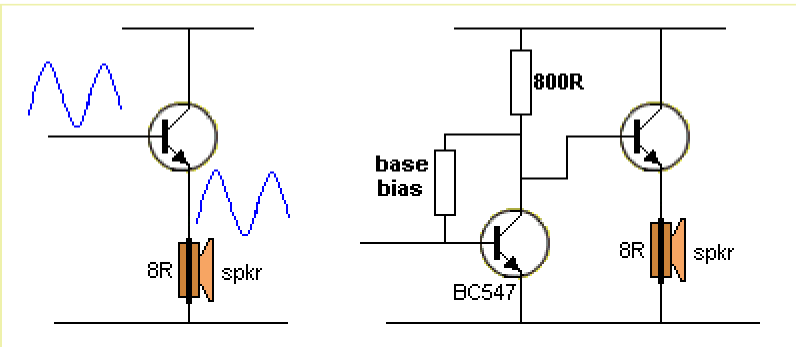


Fig 45. An emitter-follower driving a speaker

Fig 45. The **EMITTER FOLLOWER** drives a speaker.

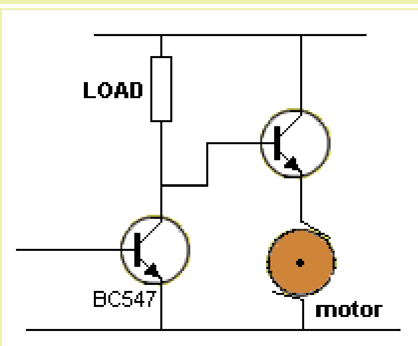


Fig 46.

Fig 46. We replace the speaker with a motor.

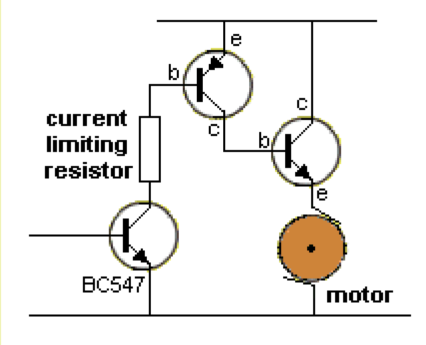


Fig 47.

Fig 47. We replace the LOAD resistor with a transistor and add a resistor called a: **Current Limiting Resistor.**
It is designed to limit the current between the first and second transistors as these will turn ON and allow a very high current to flow if the resistor is not included.

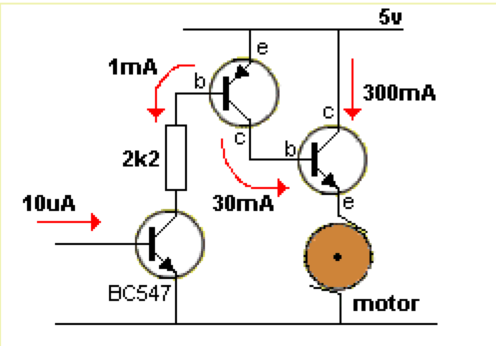


Fig 48.

Fig 48. The current required by the motor is 300mA. The emitter-follower will have a gain of 10 and the gain of the other two transistors produces the set of conditions shown on the diagram.
You can see that very little input current is required to activate the motor when 3 transistors are used.

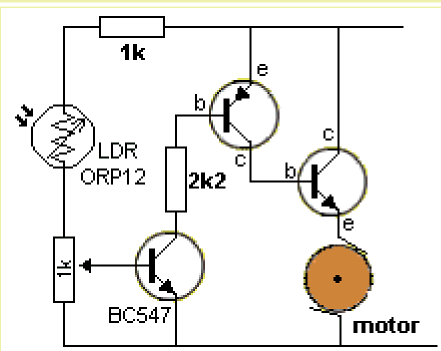


Fig 49.

Fig 49. The input current can be supplied from a voltage-divider using a pot (to adjust the setting) and a Light Dependent Resistor.
We cannot use only 2 transistors as the LDR cannot supply 1mA under low-level light conditions and that's why 3 transistors are needed.

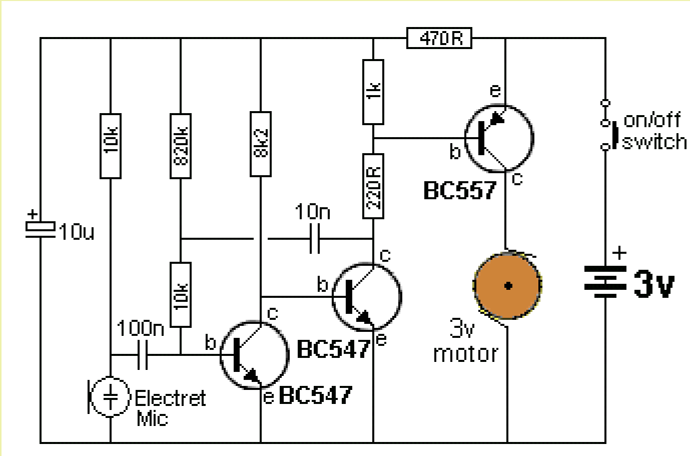


Fig 50. Dancing Flower

Fig 50. Here is a commercial version of a 3-transistor circuit.
This circuit was taken from a dancing flower. A motor at the base of the flower has a bent shaft up the stem and when the microphone detects music, the shaft makes the flower wiggle and move.
The circuit will respond to a whistle, music or noise.
The circuit uses a different arrangement to our 3-transistor design and we will discuss the differences.

It is very easy to get a change in voltage from an input device such as an LDR or electret microphone. Simply add a LOAD resistor and "tap off" the change in voltage at the join of the two components.
There is also a very small change in CURRENT at the join of the two components (but we normally refer to the change in voltage). We can amplify this voltage via two transistors to get a voltage equal to rail voltage. This is not a problem for 2 transistors. But we also need to amplify the CURRENT to operate a motor. We cannot get enough CURRENT GAIN with 2 transistors and that's why we need 3 transistors.
The change in voltage must be passed through 3 transistors to get the CURRENT GAIN required by a motor.
Both circuits (Figs 49 and 50) appear to perform the same but you need to look at the voltage drop across the leads of the output transistors to see how the two circuits compare.
There are two important values for a FULLY-TURNED-ON transistor:

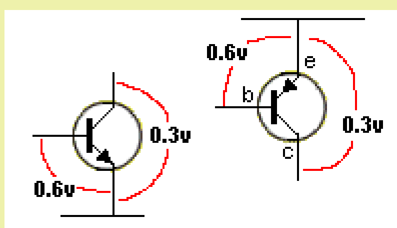


Fig 51. The characteristic voltage drops across a fully-turned-ON transistor

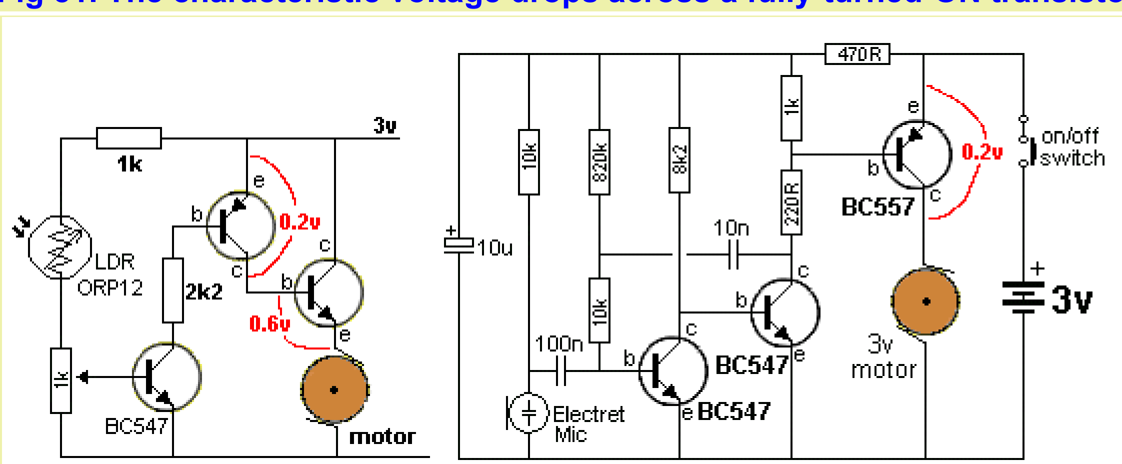


Fig 52. The voltage losses across the output transistor

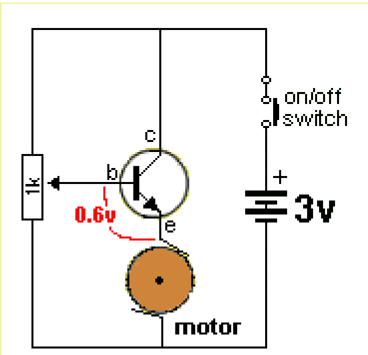
The **emitter-follower** design (the first circuit) has a total voltage drop of 0.8v and the motor will see a maximum of 2.2v. The motor in the **common-emitter** design will see a maximum of 2.8v.

SUMMARY

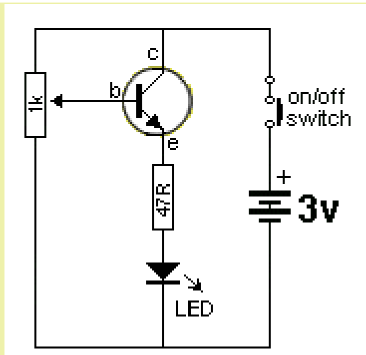
You can see the advantages and disadvantage of each design. Because the emitter-follower has a 0.6v drop between base and emitter, it is generally used in a PUSH-PULL arrangement as we will see in Fig 53, to charge and discharge the electrolytic or in an H-Bridge to drive a motor forward and reverse as shown in Fig 54. But when a common-emitter stage is used, the output voltage increases 0.6v.

THE TRANSISTOR as a LINEAR AMPLIFIER

The EMITTER FOLLOWER stage can also be called a LINEAR AMPLIFIER as the output follows the input voltage EXACTLY except it is about 0.6v lower than the input. The output has about 100 times more current capability than the input and this gives it the name AMPLIFIER. See Emitter-Follower for circuits.
A Linear Amplifier can amplify the current from a pot to create a very simple Motor Speed Controller or LED Illuminator: The actual result in increasing the speed of the motor or the brightness of the LED will not seem to be linear because they do not respond in a linear way to an increase in voltage. The pot also has to be linear to produce a linear output.



Motor Speed Controller



LED Illuminator

THE PUSH-PULL STAGE also called PUSH-PULL AMPLIFIER

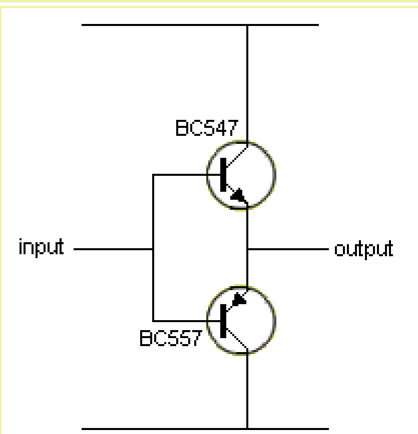


Fig 52a. Push-Pull Output

We have studied the emitter-follower in **Figs 45** to **49.** We have also shown how to connect a PNP transistor to the power rails. (It is basically a mirror-image of the NPN transistor.) Combining these facts we can produce a circuit consisting of two emitter-followers as shown in **Fig 52a.** The top emitter follower is an NPN transistor and the lower emitter-follower is a PNP transistor. The is called a **PUSH PULL** output stage or **PUSH PULL AMPLIFIER** or **Complementary-Symmetry output stage.**

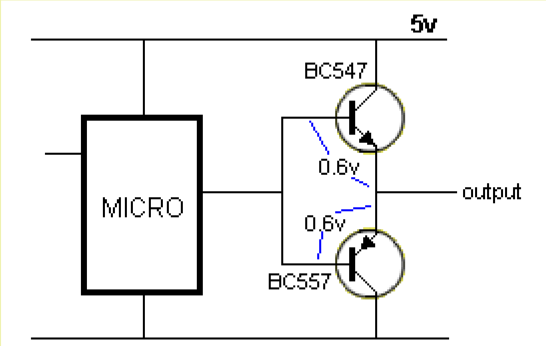


Fig 52aa. Push-Pull Output voltage will be 3.2v

The Push-Pull stage can be connected to the output of a micro to get a higher DRIVE CURRENT, as shown in **Fig 52aa**.
The Push-Pull stage does not increase the voltage - the voltage is slightly lower than the microcontroller supply voltage but the current will be increased by a factor of about 100 to 200.
The output voltage is reduced by 0.6v due to the base-emitter voltage-drop plus the output of the micro is about 0.3v less than the supply rail.
This occurs for both HIGH and LOW, making the output 0.3 + 0.6 + 0.3 + 0.6 = 1.8v less than the supply = 3.2v swing.

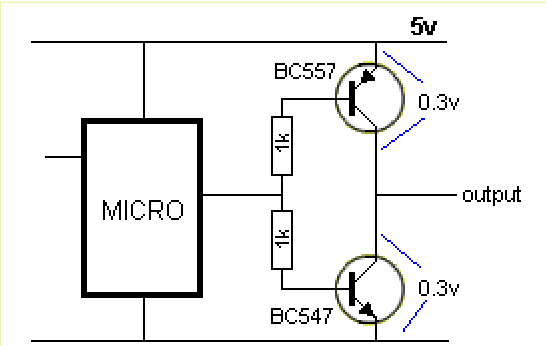


Fig 52ab. Push-Pull Output voltage will be 4.4v

The output voltage of the micro can be increased to 4.4v by placing the PNP transistor above the NPN transistor as shown in **Fig 52ab**.
Both transistors will turn ON during the time when the micro is changing from HIGH to LOW but since this is very brief, (less than 1/10th microsecond) they will not be damaged.

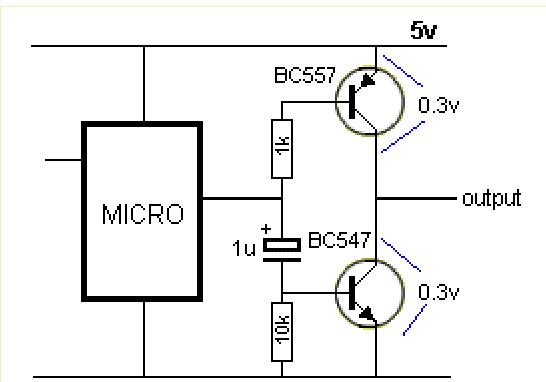


Fig 52ac. Quiescent current zero when micro output HIGH

In the circuit above, the output of the micro cannot be turned off as one transistor will be active.
The solution is to "AC couple" one of the transistors as shown in **Fig 52ac** and this will allow the micro to go HIGH and the output section will turn off.
The 1u will have an impedance of about 200 ohms when the circuit is operating at 1kHz.

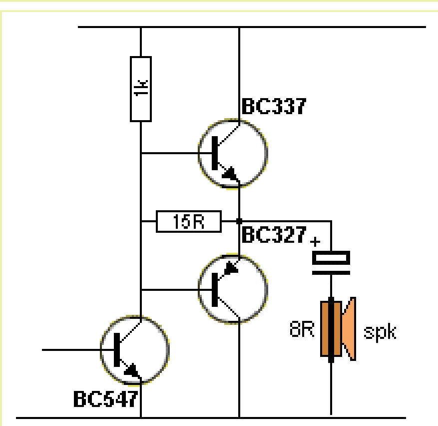


Fig 52b. Push-Pull Current Dumping

Fig 52b shows a very clever variation on the Push-Pull circuit described above.
It uses a low-value resistor between the collector of the driver transistor and output.
This resistor transfers the low-level signals directly to the speaker. As the signal-level increases, the output transistors come into operation.
This arrangement removes cross-over distortion and uses less parts.
It is called **CURRENT DUMPING**.

Lifting the Input line will raise the output line and it will have "100 times more strength." Lowering the input line will make the output line go down with "100 times more strength."
In other words this circuit turns a "weak line into a strong line."
This feature is also called **IMPEDANCE MATCHING**. The circuit is also called a **PUSH PULL OUTPUT** as one transistor "pushes energy" into a device (connected to the output) during one half of a cycle while the other transistor will "pull energy" out of a device. This is one of the ways to charge and discharge a capacitor on the output and any device connected to the other side of the capacitor will see the AC waveform and become active. This is shown in **Fig 53**:

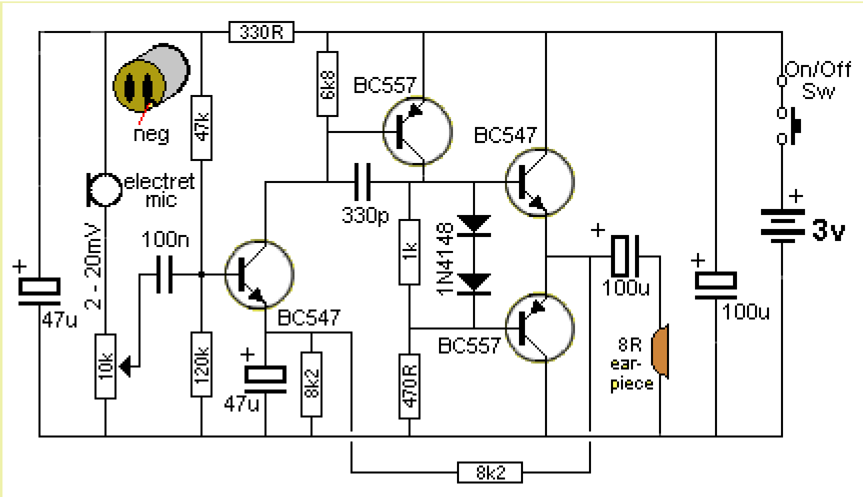


Fig 53 PUSH-PULL to charge/discharge the 100u electrolytic

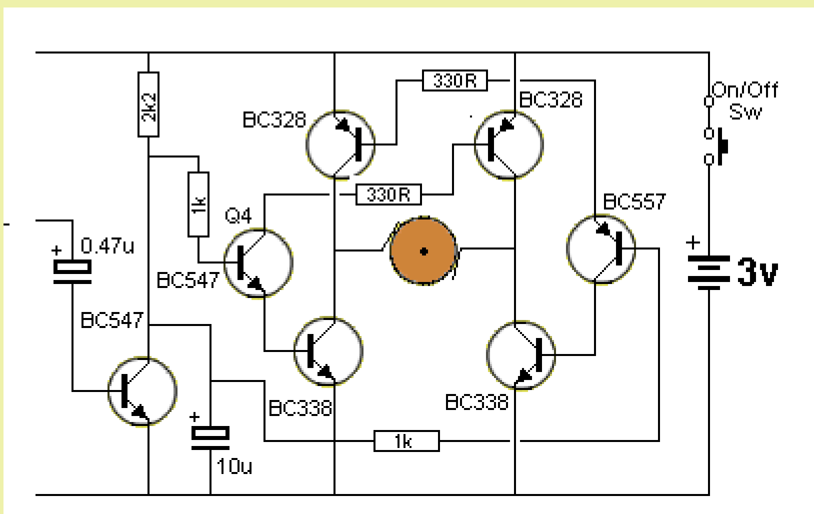


Fig 54 PUSH-PULL driving the motor forward/reverse

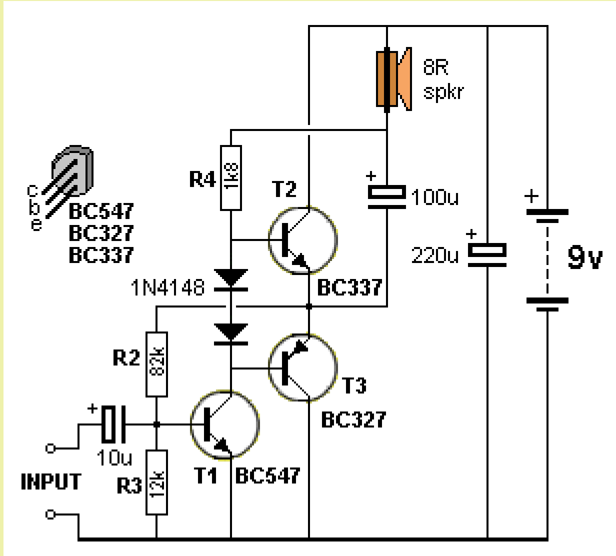


Fig 54aa PUSH-PULL Amplifier

Fig 54aa is a 3-Transistor Push-Pull amplifier.
When the supply is turned on, current flows though the 8R speaker and through R4 to the base of T2. This pulls the base of T2 towards the 9v rail and the transistor rises to nearly the 9v rail. The voltage on the emitter of T2 is 0.6v lower than the base and this pulls the emitter of T3 towards the 9v rail. The base of T3 is 0.6v lower than the emitter.
This is as far as we can go with the current-path at the moment and we now have to go to T1.
The join of the two emitters has a voltage near the 9v rail and this voltage is passed to the base of T1 via the 82k resistor.
The 82k resistor forms a voltage divider with 12k and the resulting voltage at their join is sufficient to put 0.6v on the base of T1. This turns ON T1 and the voltage between collector and emitter drops to a low value. The exact value will be shown in a moment.
We can now go back to the base of T3 and continue the current-path (also called the voltage path) from the 9v rail to the 0v rail.
T1 pulls the base of T3 towards the 0v rail.
We now have three transistor that all turn on. They are not fully turned on but partially turn on.
The exact amount of “turn-on” for each of the transistors is due to the 83k and 12k biasing components and diodes D1 and D2.
Here’s how the DC coupled amplifier self-adjusts to a state called the QUIESCENT STATE. This is the state where some of the components adjust the “turn-on” of other components and the circuit reaches a point where the voltages settle down and reach a stable value and the current is a constant minimum value.
The voltage at the midpoint of the two output transistors is fairly high and this creates a slightly higher voltage on the base of T1. This turns on T1 slightly more and the voltage on the collector drops. This lowers the voltage on the base of T3 and the emitter voltage drops. This lower voltage is passed to the base of T1 and the transistor turns OFF slightly.
This is how the three transistors adjust themselves to a final value.
The exact final voltage is called a DESIGN VOLTAGE and designer of the circuit want the voltage on the join of the two emitters to be half-rail-voltage.
This allows the circuit to rise and fall and reproduce a waveform without clipping or cutting off the top or bottom of the wave.
To get the circuit to sit with the output (the join of the two emitters) at 4.5v, the values of R2 and R3 have been selected.
We now have the circuit sitting, ready to amplify a signal.
The output stage is called PUSH PULL because one transistor pushes current through the winding of the speaker via the 100u electrolytic and the other transistor pulls current through the speaker via the electrolytic.
You could connect the speaker directly to the output of the stage and remove the electrolytic. The circuit would work just the same.
However if the speaker is connected directly, a voltage of 4.5v will be paced across the speaker and this voltage will cause a current to flow in the winding of the peaker (the voice coil) and the cone will

be pulled in. If we try to reproduce a waveform, the cone is already partially pulled-in and it will not reproduce half of the waveform.
In addition, this constant current will heat up the voice coil.
By adding the 100u, we remove the Dc component of the output and only the AC (waveform) will be passed to the speaker.
Now we have to understand how an electrolytic passes energy (current) to the speaker.
If you connect an electrolytic and speaker directly to a supply, you will hear a “plop” This is the electrolytic charging and the charging current flows through the speaker and produces the noise.
But after a very short time the electrolytic is charged and no ore current flows.
Even if you remove the supply and connect it again, no sound will be reproduced because the electrolytic is already charged.
The only way to hear another plop, is to remove the components and short between the power leads.
When the supply is re-applied, you will hear another plop.
To get sound from the circuit, this is what it has to do.
Firstly it has to charge the electrolytic. Then it has to discharge the electrolytic.
As you can see from the circuit, the lower transistor charges the electrolytic and the top output transistor discharges the electrolytic.
Now we have to drive the two transistors so that they charge and discharge the electrolytic.
To charge the electrolytic, T1 turns ON and pulls T3 towards the 0v rail.
This is the easy part.
How do you pull T2 UP so that it discharges the electrolytic?
This is how it is done. It is very clever.
Connected between T2 and T3 are two diodes. Each if these diodes has a voltage drop of 0.6v.
This voltage drop is exactly the same voltage as between the base and emitter of the two transistors in the output.
This means we can directly pull on the base of the top transistor, just like we are directly pulling on the base of the lower output transistor.
Now we have a situation where we can pull down on both transistors and this will turn ON the lower transistor and turn OFF the upper transistor.
This is done when T1 turns ON.
When T1 turns OFF, the top transistor is pulled HIGH via the 1k8.
That’s how it works.

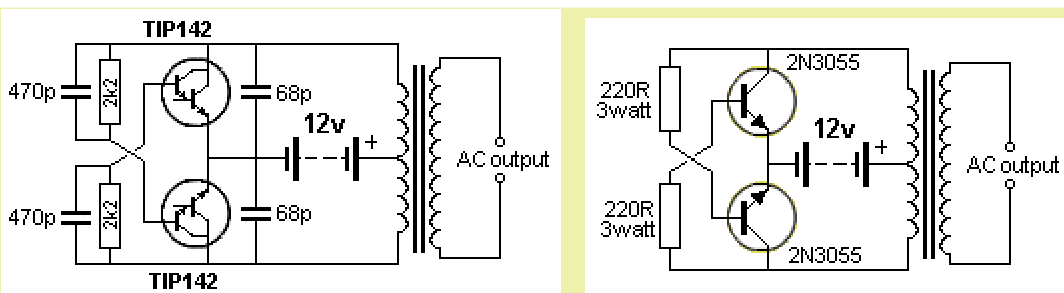


Fig 54a Two Push-Pull circuits driving the primary of a transformer

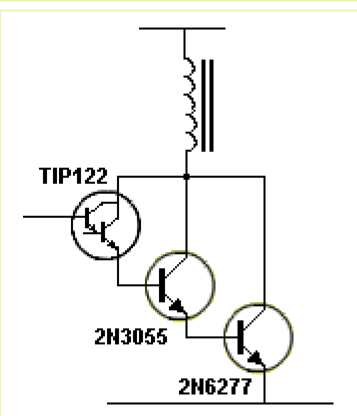


Fig 54ab.   A High-current Driver stage - faulty design

Fig 54ab shows an actual high-current driver stage of a 500 watt inverter, taken from the web.
The designer of the circuit has tried to provide a high-current capability for the 2N6277 by driving its base via a 2N3055 and TIP122. Theoretically the base current for the TIP122 will be only a few milliamps as the gain of the Darlington transistor and 2N3055 will deliver a high base-current to the output transistor.
However this circuit is a faulty design.
For the 2N3055 to deliver current into the base of the 2N6277, it must have a collector voltage that is higher than the emitter.
And for the TIP122 Darlington transistor, it must have a collector voltage that is higher than its emitter.
The minimum collector-emitter voltage for a Darlington transistor is 2v.
The base-emitter voltage for a 2N6277 is about 1.8v to 3.5v (use 2.1v) and for a 2N3055 it is about 0.7v.

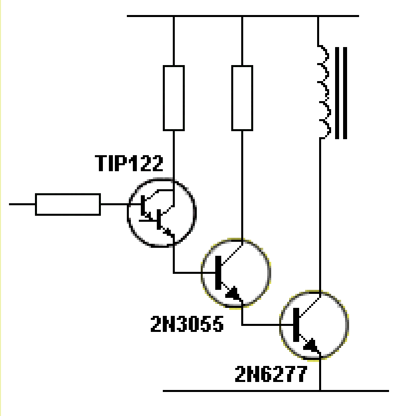


Fig 54ab-1. A High-current Driver stage - improved design

This means the TIP122 can only turn on when the collector voltage is 0.7v + 2.1v + 2v = 4.8v.
This means the collector of the 2N6277 cannot be less than 4.8v.
This faulty design can be fixed by taking each of the transistors to the supply-rail via a suitable resistor.
The collector-emitter saturation voltage for the 2N6277 is between 1v - 3v.
This means the transformer sees a higher voltage.
This improvement will make an enormous difference in the output capability of the circuit and reduce the heat generated in the output transistor(s).

The author of the 500 watt inverter:
http://www.instructables.com/id/250-to-5000-watts-PWM-DCAC-220V-Power-Inverter/
did not understand the fault with his circuit, so let me explain:

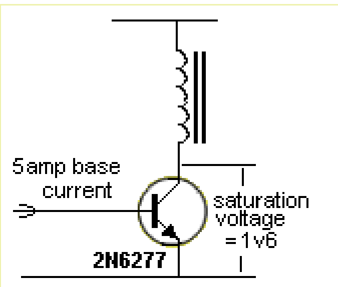


Fig 54ab-2. An ideal way to drive an inductor.

When using a 2N6277 transistor on each leg of the output, the base must receive about 5 amps to fully saturate the transistor for 40 amp collector current.
The circuit on the left is an ideal way to drive an inductor.
The transistor will handle 40 amps to produce a 500 watt inverter.
The voltage on the collector will be about 1.6v so that for a 12v supply, the inductor will see 12v - 1.6v = 10.4v.

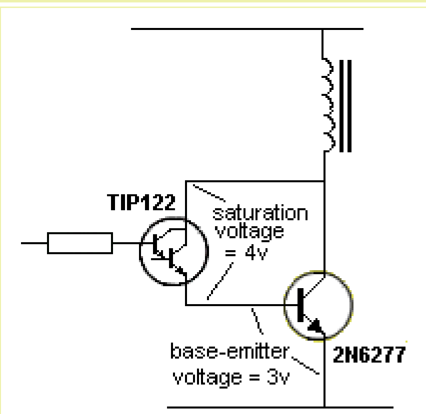


Fig 54ab-3. This arrangement is a very bad design.

However when you drive an output transistor as shown in Fig 54ab-3, two problems arise.
To deliver 5 amps to the base of the 2N6277, the TIP122 transistor has a saturation-voltage across its collector-emitter leads of about 4v.
We will explain this in a moment. Firstly e have to go to the 2N6277 and cover the fact that the base-emitter voltage will be about 3v for a collector current of 40 amps.
The TIP122 is now sitting 3v above the 0v rail and the collector must see a voltage of 7v so that it can deliver 5 amps to the base of the 2N6277.
This means the collector of the 2N6277 cannot go below 7v.
In other words we are losing 7v from the 12v supply and only 5v will be available for the inductor.
This method of driving an output transistor is a very bad design.

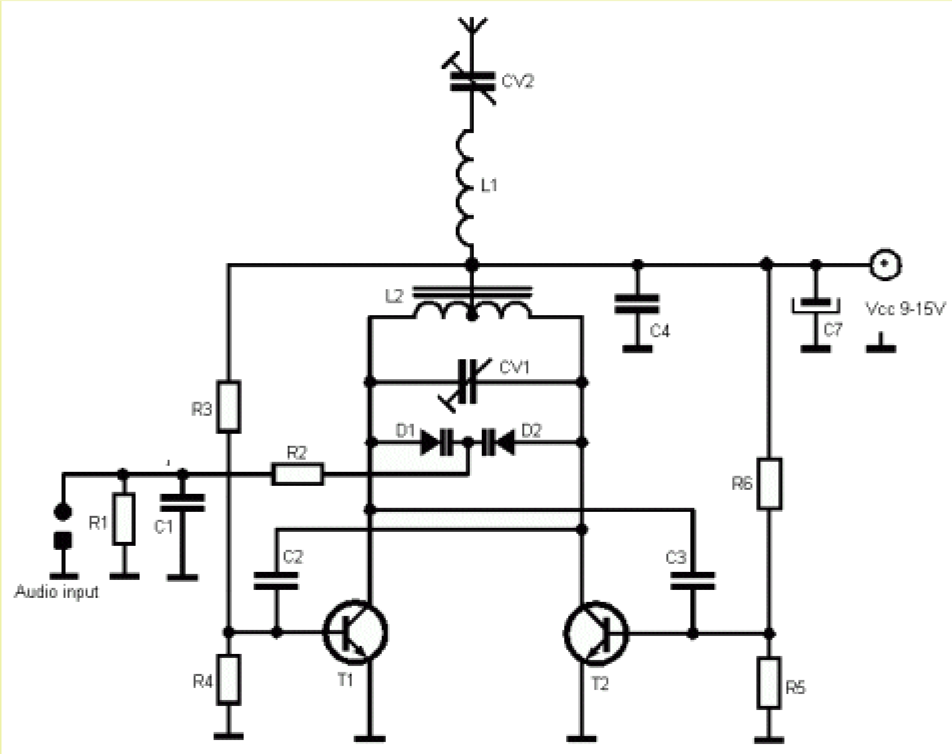


Fig 54bbb

Fig 54b shows a free-running multivibrator configured so the transistors drive a transformer in **Push-Pull**

THE TOTEM POLE OUTPUT STAGE

A slightly different push-pull output stage can be created with two NPN transistors. It is called a Totem Pole Output stage.

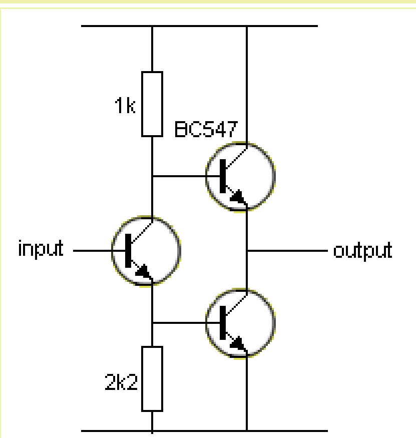


Fig 55a

Fig 55a. When the input is less than 1v, the output is pulled high via the 1k resistor and the "strength" of the "pull-up" will be 1,000/100 = approx 10 ohms.
When the input reaches 1.4v, the output is pulled low via the lower transistor and will about 0.2v from the 0v rail. The "strength" of the "pull-down will be about equivalent to a 10 ohm resistor.
This is about the same as the output driving capability of a normal Push-Pull arrangement, however there is a mid-point where both transistors are turned on at the same time and this produces a large current that can overheat the transistors or damage them.

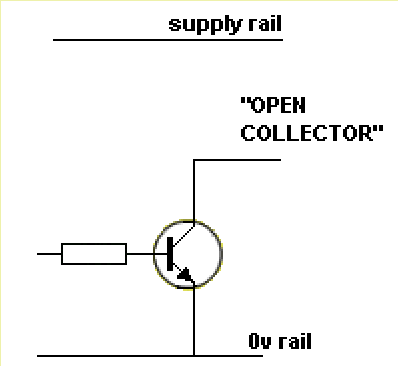
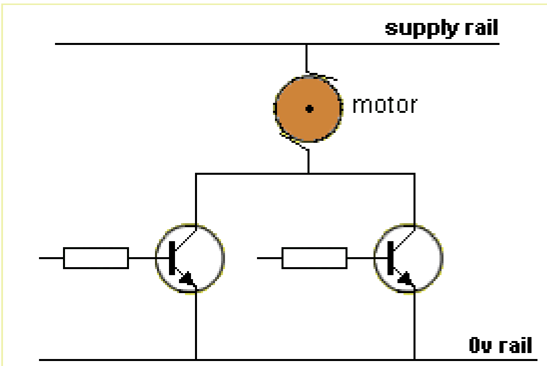


Fig 55b "Open Collector" Output

OPEN COLLECTOR

Fig 55b. The circuit **Fig 55a** above is used in many applications because it will drive the output **HIGH** and **LOW**. In other words a transistor will pull the output HIGH and the other transistor will pull it LOW. The output of many (most) integrated circuits will **SINK** (pull the output **LOW**) and **SOURCE** (pull the output **HIGH**). This is called PUSH-PULL or more-accurately: TOTEM-POLE output.
When it is **SINKING**, current flows through the load (from the supply) and the output acts like a "switch" to connect the load to the 0v rail.
When it is **SOURCING**, the output delivers the current to the LOAD and the load is connected to the 0v rail.

But if the output can only **SINK** as shown in **Fig 55b**, it is called "**OPEN COLLECTOR**."
This means a LOAD must be connected to the supply rail and the output will "switch" (connect) it to the 0v rail.



You can have the situation where a device (such as a motor) is driven by two different circuits (two different transistors).
This is called an **OR** situation and because either transistor will operate the motor. Because the connections are "wires" it is called a "wired-**OR.**"
The transistors are sinking the LOAD and you cannot get any "short-circuits" across the supply rail.

TRI-STATE

In the diagram above (Fig55b) you can see the output wire (line) is connected to the collector of the transistor. When the transistor is OFF, it can be considered to the removed from the circuit and if you measure the resistance between the output line and either the supply rail or 0v rail, the resistance will be very high (infinite). This is called open collector.

If we can create the same effect with Fig55a we can produce an output that will pull HIGH and LOW and also "switch-off" so the output goes **HIGH IMPEDANCE**.
This effect is not possible with any of the circuits we have studied but is available with some IC's and many microcontrollers.
It is called **TRI-STATE**.

How can we detect a TRI-STATE line?
1. Read the documentation that comes with the product or datasheet.
2. Put the project into a state of HIGH IMPEDANCE and place a 47k from the line to rail-voltage and another 47k from the line to 0v.
Measure the voltage at the junction. It will be half-rail-voltage.

THE BRIDGE **(actually Bridge Biasing)**

Another way to connect a transistor to produce a "stage" is called a BRIDGE. It consists of 4 resistors:

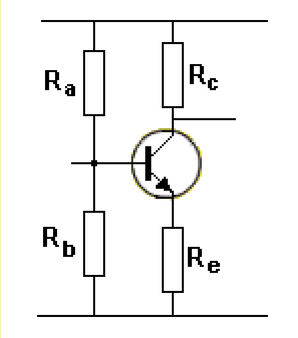


Fig 56. A BRIDGE arrangement consisting of 4 resistors

Fig 56. We have already studied the purpose of Ra and Rb to produce a voltage on the base of the transistor. If they are the same value, the base voltage will be half the supply. We also know the emitter voltage will be 0.7v lower than the base.
This will produce a current through Re and the same current will flow in Rc. We can now work out the voltages on the three leads of the transistor.

But that's not the point of our discussion at the moment.
We want to know how to work out the values of Ra, Rb, Rc and Re.
There are two types of "bridges."
1. A small-signal bridge and
2. A medium or high-power signal bridge.

A small-signal bridge deals with signals that do not have much input-current. We have already learnt the ability of a stage to pass a CURRENT from one stage to the next stage depends on the value of the LOAD resistor (for the common-emitter stages we have covered).
If this current is very small, we do not want to attenuates it (reduce it) by making the input of our bridge stage LOW IMPEDANCE (low resistance). If the values of Ra and Rb are low, any signal being applied to this stage will be partially lost (reduced - attenuated) by the value of the voltage-divider. That's why the resistors have to be as high as possible.
They are generally about 470k to 2M2.
Suppose we make Ra = 1M and Rb = 470k.

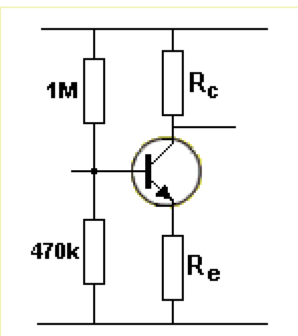


Fig 57. Biasing the BASE

Fig 57. The base is biased at about 1/3 rail voltage.
The emitter will be about 0.7v below the base voltage so the collector can produce a swing of about 50% of rail voltage.
This is the normal way to bias this type of stage.

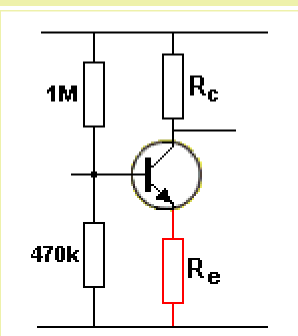
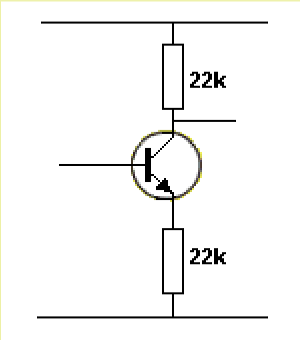


Fig 57a. The emitter resistor provides NEGATIVE FEEDBACK

Fig 57a. In the **Bridge Circuit**, 4 resistors bias the transistor and Re is the EMITTER RESISTOR.
It is also a NEGATIVE FEEDBACK resistor and works like this:
When the voltage on the base rises by 10mV, the transistor turns on more and the current through the collector LOAD resistor Rc increases and the same current flows through the emitter resistor Re.
This causes a slightly higher voltage to appear across this resistor and the voltage on the emitter rises.
We have already discussed how to turn ON a transistor or turn OFF a transistor and when the voltage on the emitter increases, the transistor is turned OFF slightly. This means the 10mV rise on the base may be offset by a 2mV rise on the emitter and the transistor will not be turned on as much. This is the effect of **NEGATIVE FEEDBACK.**

STAGE GAIN



The gain of the stage is the ratio of Rc/Re
If we have a collector resistor of the same value as the emitter resistor, the stage will have a gain of 1. In other words, it will not have an increase in the amplitude of the signal. The output signal will be the same amplitude as the input signal. (But the output current will be - or may be - larger.)
The collector resistor can be from 100R to 1M and the emitter resistor can be from 100R to 1M. When the two resistors are the SAME VALUE the stage will have a gain of ONE.

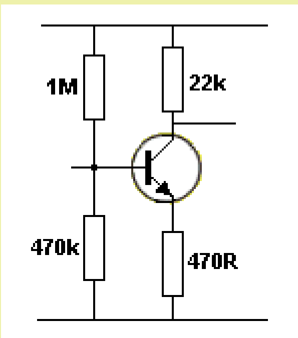


Fig 58. A stage-gain of 46

If Rc=22k and Re=470R the gain is 46. It does not matter if the transistor has a gain of 200 - the stage is limited to a gain of 46. The actual DC voltage on the leads of the transistor depends on the quality of the transistor (its gain) and we will not be concerned with these values as the stage will have a capacitor on the input and output and it will be biased by the 4 resistors.

Fig 58. shows a stage with Rc=22k and Re=470R, producing a stage-gain of 46. The actual voltage on the collector will depend on the gain of the transistor.

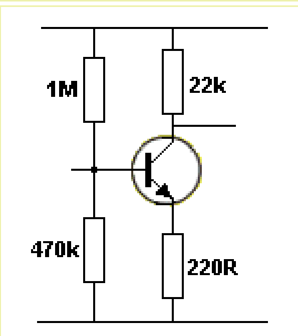


Fig 59. A stage-gain of 100

Fig 59. If we use the values: Rc=22k and Re=220R the gain will be 100.

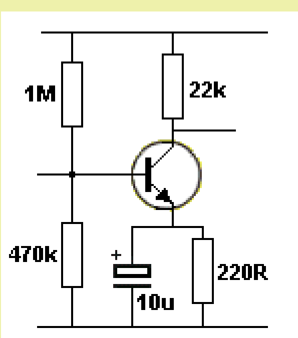


Fig 60. A stage-gain of 200 or more

Fig 60. If we add an electrolytic across the emitter resistor, the emitter will not move up and down when a signal is processed and this makes the transistor similar to a common-emitter stage. The transistor will now have a stage-gain similar to its specification. It may be 200.
The gain of the stage will also depend on the frequency. It will have a higher gain with high frequencies as the capacitive-reactance (resistance) of the 10u will be lower at high frequency. However the capacitor on the input will produce losses from one stage to the other and the capacitor on the output will reduce the gain of this stage.
That's why it is very difficult to specify the gain of this and any other stage.
In most cases you can count on a gain of 50 to 70 when a stage is incorporated in a multi-stage design.

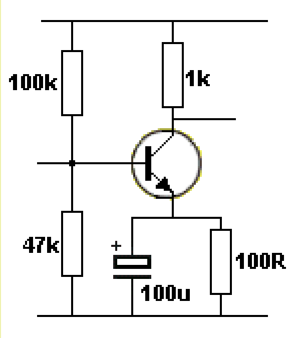


Fig 61. A medium-power bridge circuit

Fig 61. When we add the electrolytic, the gain of the stage is not dependent on the values of Rc and Re, and we can reduce the value Rc (the resistor on the collector) so the stage will pass a higher current to the following stage.
This stage is called a **medium-signal stage.**
The stage will also have a higher gain at high frequencies.
The electrolytic is called a BY-PASS capacitor because any signal that appears on the emitter is passed (sent) to the 0v rail.
This capacitor can also be called a SHUNT capacitor as it "shunts" (sends) the signal to the 0v rail. In other words, the electro connects the emitter to the 0v rail just like a very low value resistor (about 10R).

ADJUSTING (SETTING) THE STAGE GAIN
EMITTER DEGENERATION - or EMITTER FEEDBACK

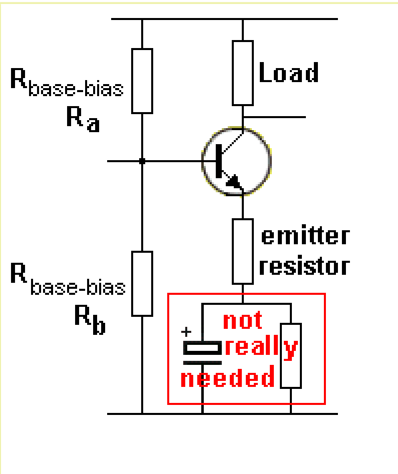


Fig 61a. "emitter resistor" adjusts the gain of the stage

Fig 61a. The gain of a stage can be adjusted (or SET) to a particular value by adding an emitter resistor. We have seen in Fig 58, the gain of a stage is determined by the ratio of:
the resistor in the collector/ the resistor in the emitter.
Increasing the value of the resistor in the emitter, decreases the gain of the stage.
In Fig 57a, we saw this as **NEGATIVE FEEDBACK**. This effect is also called **EMITTER DEGENERATION** as it reduces the gain of the stage.
On Page 2 of this eBook you will find a program where you can design your own Transistor Amplifier:
Design Your Own Transistor Amplifier
It uses the circuit in Fig 61a to adjust the gain of the amplifier.
The components in the red rectangle are not really needed when the resistor called: **emitter resistor** is used. They only adjust the "setting of the transistor" slightly up or down between the supply rails.

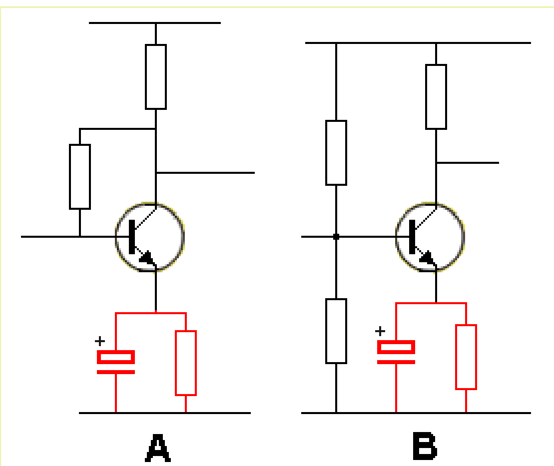


Fig 61aa. The electrolytic increases the gain at high frequencies.

Fig 61aa. shows two circuits with an electrolytic and resistor in the emitter.
Why have these components been added?
Firstly they will reduce the gain of the stage in circuit "A" but the high frequencies will be amplified more than the low frequencies. This is because the capacitive-reactance (resistance) of the electrolytic will be low at high frequency and prevent the emitter rising and falling and gives the stage a higher gain at high frequencies.
In circuit "B" the electrolytic also allows the circuit to produce a higher gain at high frequencies without changing the DC biasing arrangements of the 4 resistors.

MORE DETAILS ON THE GAIN OF A STAGE:

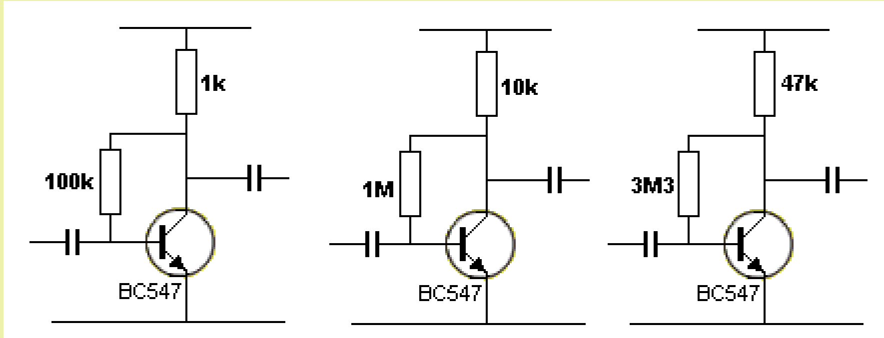


Fig 61b. Three circuits with the same gain.

The three circuits above have (approximately) the same gain (amplification). The gain will be about 70-100. Even though the transistor may have a DC gain of 200-400, the base-bias resistor is acting AGAINST the incoming signal and this creates a reduction in gain.
However we are looking at the idle-current (quiescent-current) and aiming to reduce this to a minimum for long battery life.
The first circuit takes a high quiescent current because the load resistor is 1k. The second circuit takes about one-tenth the current and the third stage takes less.
Minimum quiescent current is necessary when designing a battery operated project. But you must also take other things into account - such as the ability of the stage to deliver the maximum signal to the next stage.
In this article we will explain the fact that a stage passes energy (signal) to the next stage via the output capacitor and the value of the load resistor.
The first circuit above is capable of delivering a high signal to a next stage in your project whereas the second circuit has only one-tenth the capability of delivering a signal. And the third stage delivers even less.
If you don't match-up the driving capability of one stage with the next, the gain of the stage will be very low and you will wonder why the project is not working.
Start with a "high-current-stage" (circuit1) and gradually increase the value of the load resistor and change the value of the base-bias resistor to get mid-rail voltage on the collector.
A point will come where the transfer of signal is a maximum and you will have achieved the minimum current for the stage with maximum gain.
In general, a higher rail-voltage will produce higher gain and this is most-noticeable when increasing rail voltage from about 3v, to 6v to 9v.

Connecting a small-signal stage to a medium-signal stage:

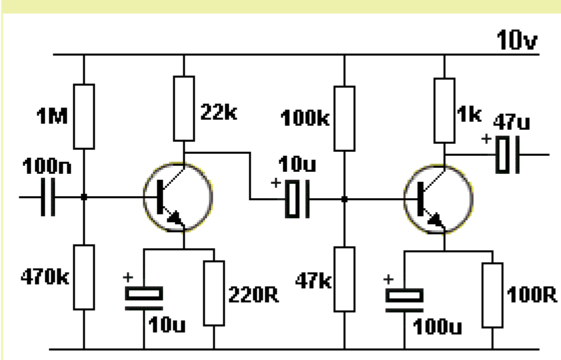


Fig 62. Connecting a small-signal stage to a medium-signal stage

Fig 62. When describing small-signal and medium-signal stages we are referring to the size of the waveform (voltage waveform) and also the CURRENT they are capable of transferring. The two values normally go together.
In most cases the voltage AND current increase as it progresses though each stage.
Both stages in Fig 62 produce a high gain but the final gain will depend on the amount of energy each capacitor will transfer.
For instance, the 22k will pull the 10u high but the 47k discharges the 10u and so it will be partially charged for the next cycle. This means the energy transfer will only be equivalent to a load resistor of 47k.

COMMON BASE AMPLIFIER

We have discussed the importance of matching the output impedance of one stage to the input impedance of the next stage. When the two are equal, the maximum energy is transferred.
Suppose you want to match a very low resistance device (such as speaker or coil) to the input of an amplifier. The speaker may be 8 ohms and the input impedance of the common-emitter amplifiers we have described are about 500R to 2k. The two can be connected via a capacitor but we have already mentioned how a capacitor transfers only a small amount of energy when the two impedances are not equal. And when the two impedances are so mismatched as 8:2,000, the transfer may be very poor.
The answer is to use a stage that has a very low input impedance.

That's a **COMMON BASE** amplifier.

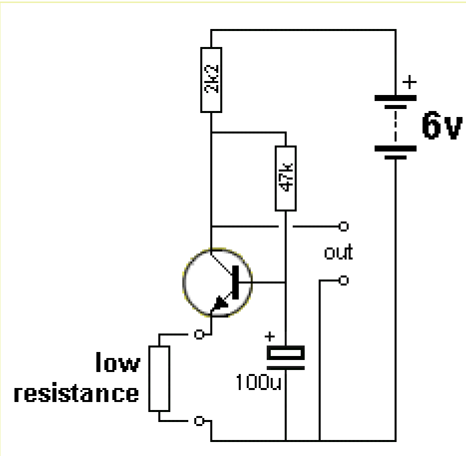


Fig 63.

Fig 63. The common-base amplifier (Common-Base stage) accepts a low value of resistance on the input and produces a high gain. Since the input is directly coupled to the transistor, there are no losses.
We have already mentioned two ways to turn ON an NPN transistor.
1. Hold the emitter fixed and RAISE the base voltage.
2. Hold the base fixed and LOWER the emitter voltage.

We are using the second option. The base is held rigid (as far as signals are concerned) and any rise or fall in voltage on the emitter appears on the collector with a voltage increase.

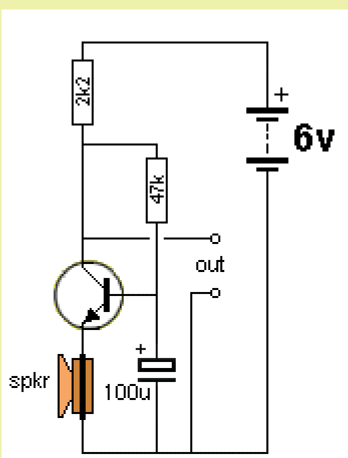


Fig 64. Dynamic Microphone

Fig 64. This circuit converts an ordinary speaker into a very sensitive microphone.
The fact that the load resistor is (a **low**) 2k2, means the stage has a good capability of delivering energy to the next stage.
We have already discussed the fact that the "load" resistor determines the capability of the stage to pass energy to the next stage.
Here are the details of the gain to expect from the stage:
The impedance of the speaker is 8 ohms. Suppose we generate a voltage of 1mV from the speaker. This voltage will produce 1/8mA in the emitter-line.
The collector current is almost the same as the emitter-current and thus the voltage produced across the 2k2 will be 2,200/8 = 275mV. Thus the gain of the circuit is 275.
We are already assuming the voltage on the collector is 3v and the 47k has been selected to create this 3v. The collector can increase by 2.75v and decrease by 2.75 before clipping occurs and thus the speaker can produce a 20mV p-p before clipping.

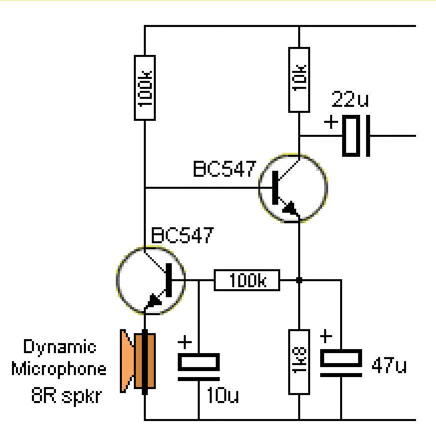


Fig 64a. Common Base and Common Emitter stages directly coupled together

Fig 64a. This circuit adds a Common Emitter stage to the Common Base shown in Fig 64 to produce a DC coupled (Directly Coupled) amplifier with very high gain.
The common-emitter transistor can be called a BUFFER stage as it provides a lower impedance output than the first stage.
In Fig 71ac, (below) the output of the second transistor has been taken back to the input to produce an improvement called a **BOOTSTRAP Circuit** to create a higher gain.

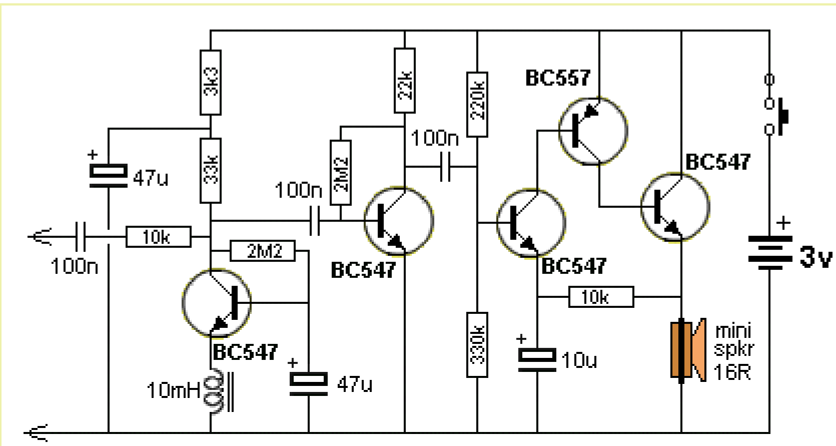


Fig 65. Hum Detector

Fig 65. This circuit picks up mains hum via a coil. The common-base first stage has very high gain. And we can see a common-emitter stage plus a 3 transistor DC amplifier driving a speaker.
All the things we have learnt, put into a single circuit.

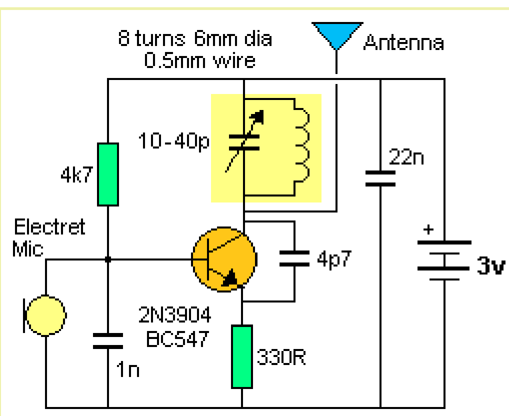


Fig 65aa. FM Transmitter

Fig 65aa. The common-base amplifier can be found in many FM transmitter circuits. The electret microphone and 22n capacitor do not form part of this discussion, but the tuned circuit made up of the 8 turn coil and 10-40p capacitor form a TANK CIRCUIT and this will also be covered.
We will start the operation of the circuit with the 4k7 base-bias resistor turning ON the transistor.
The 1n capacitor is designed to hold the base rigid and at the moment it charges as the base voltage rises to turn on the transistor.
As the transistor turns ON, two things happen.
Current flows through the 330R emitter resistor (and a voltage develops across it). And current flows through the 8 turn coil.

The coil produces magnetic flux. We call this expanding flux and we draw arrows coming out of the coil. There is a very small voltage produced across the coil during this time and the voltage gradually increases. This means the voltage on the collector is becoming less than the 3v rail voltage. (The 22n is designed to hold the rail voltage rigid.)
This voltage is being passed though the 4p7 and is lowering the voltage on the emitter.
There are two ways to turn on a transistor.
1. Raise the base voltage with respect to the emitter or

2. Lower the emitter voltage with respect to the base.
This is what the circuit does.
The base is held rigid via the 1n and the emitter voltage is being lowered. This action turns on the transistor more and more until it is fully turned ON. At this point the flux being produced by the coil is a maximum but it is not increasing. This means the voltage on the collector is not reducing. In other words it is remaining stationary at some voltage that is lower than rail voltage. This means the pulse of energy through the 4p7 does not push the emitter voltage lower and the transistor is turned off a small amount by the increasing voltage-drop across the 330R.
The current through the coil reduces and the magnetic flux surrounding the coil starts to collapse.
This produces a voltage across the coil THAT IS IN THE OPPOSITE DIRECTION.
The voltage on the collector starts to rise and this action is passed through the 4p7 to the emitter.
The voltage on the emitter rises and the transistor starts to turn OFF.
This action continues until the transistor is fully turned off.
This all happens very quickly and the magnetic flux collapses very quickly and cuts the turns of the coil to produce a voltage that is much higher than the original voltage across the coil.
The ratio of the original voltage to the final voltage is called the "Q" of the coil and it can be 10 or even 100 times higher than the original and provides the signal that is passed to the antenna.
The capacitor across the coil simply charges and discharges during the cycle and the delay it creates produces the frequency of operation of the circuit.

BASE BIAS

There are a number of ways to bias the base of a transistor so it is turned on a small amount or just at the point of turning on.
There are reasons why a transistor is biased in different ways.
If is it biased so it is just at the point of turning ON, it does not consume any current when in quiescent mode (idle mode) and is ideal for battery operation.
However the transistor will not amplify the first part of a waveform as it will be less than the 0.6v needed to start to turn the transistor ON.
If it is turned ON so the collector is half-rail voltage, it will amplify both the positive and negative parts of the waveform.
If it has a resistor in the emitter, the current into the base will never damage the transistor. This is not strictly "base-biasing" but base-current-limiting.

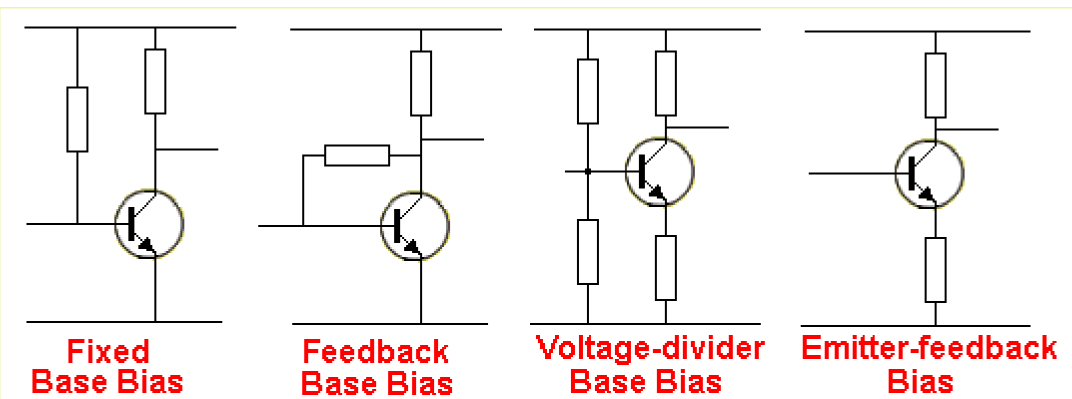


Fig 65a. Four ways to bias a transistor

The voltage on the collector of a transistor using **Fixed Base Bias** will alter according to the actual gain of the transistor. This is not a reliable way to bias a transistor.
Feedback Bias. The collector voltage is set by selecting the value of the two resistors in this diagram and if different transistors are used, the collector voltage will not alter as much as the Fixed Base Bias arrangement. Feedback base Bias is also called **SELF BIAS**. It gets negative feedback via the feedback resistor.
Voltage-Divider Bias is also called **BRIDGE BIAS** and produces a very stable collector voltage over a range of transistor parameters and temperature ranges.
Emitter-feedback Bias uses a resistor in the emitter to allow the base to rise above 0.7v without damaging the transistor. The emitter resistor is also called **EMITTER DEGENERATION** or **EMITTER**

FEEDBACK. It produces negative feedback.
Negative feedback is **STABILISATION FEEDBACK**.

Fig 65b shows a transistor with a gain of 175 and 350 in a circuit. The collector voltage is 3.5v ofr the first transistor. If a transistor with a gain of 350 is placed in the same circuit, the collector voltage will fall to 1.75v. If the stage has a capacitor on the output and the waveform is less than rail-to-rail, the different gains will not affect the overall amplification of the stage. Although the gain of the two transistors is different, the approx gain that will be produced by this circuit is about 70 and this applies to a transistor with a gain of 175 or 350. The BASE BIAS resistor produces negative feedback and it reduces the effective gain of the circuit to about 70.

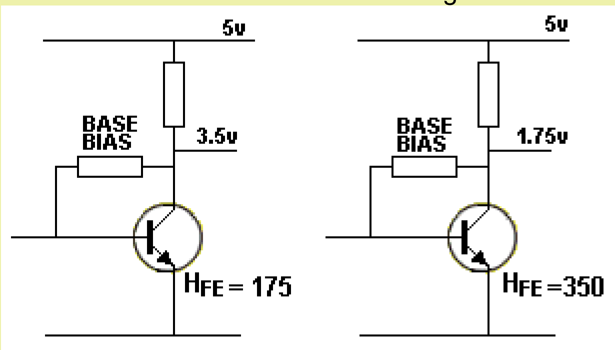


Fig65b

In conclusion: The gain of the circuit is about 70.
The collector voltage will fall when a high-gain transistor is used.
If the circuit is producing a waveform of about 1500mV, the output will be the same for either transistor.
If the waveform of these circuits is viewed on a CRO, the first transistor will be producing the 1500mV waveform towards the top of the screen on the CRO and the high-gain transistor will produce the waveform towards the lower part of the screen.
When this waveform is passed though an output capacitor it does not matter where the waveform is generated on the CRO.

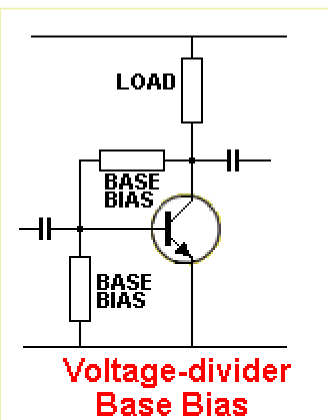


Fig 65c

Fig65c shows a common-emitter transistor and two **BASE BIAS** resistors.
This arrangement is the simplest and best way to create a mid-voltage on the collector and maintain the same mid-voltage for a range of transistors with different gains.
However the circuit requires 5 times more energy from a previous stage to achieve the same amplitude as the arrangement in **Fig 65b**.
This is the same as saying the stage will produce a gain of: 70/5 = 14.

In conclusion: To achieve a constant mid-rail voltage you have lost 80% of the gain and created a stage that takes more current.
That's why this form of biasing has not been covered in this eBook.

Now go to:
Configurations - summary of features of Common Emitter, C-Collector, and Common Base

PRACTICAL CIRCUITS

Here are a number of circuits using the stages we have covered:

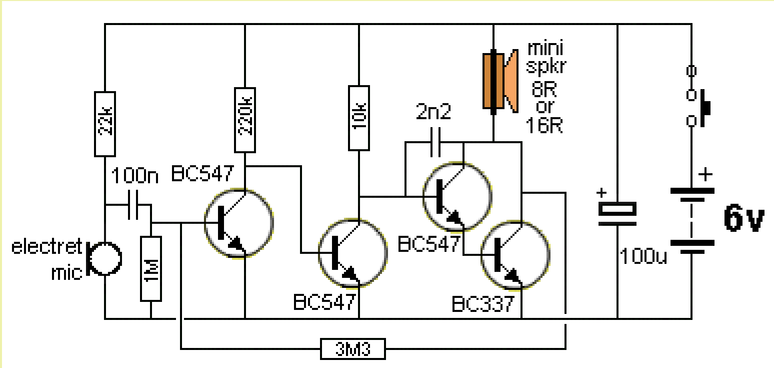
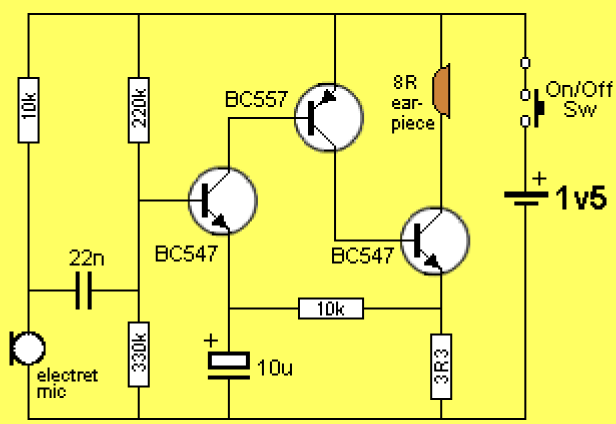


Fig 66. 4-Transistor Amplifier

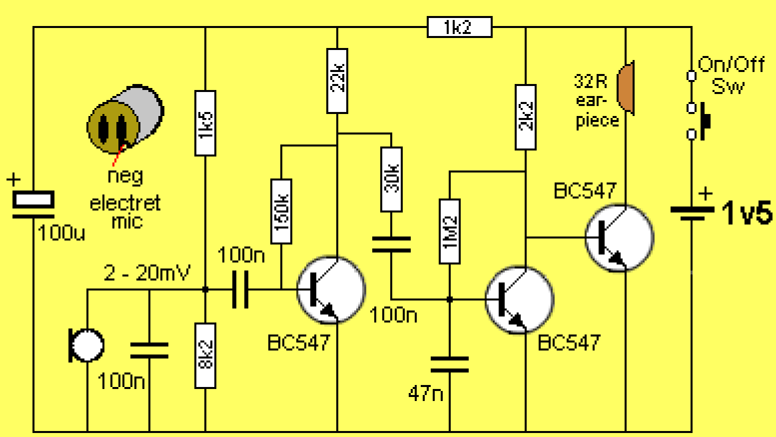
Fig 66. This 4-transistor amplifier uses the minimum of components and has negative feedback via the 3M3 to set the voltages on all the transistors. It is actually 3 stages and that is why the feedback can be taken from output to input. Transistors 3&4 are equivalent to a single transistor called a Darlington transistor and this is covered in Fig 71.



HEARING AID 1.5v SUPPLY

Fig 67.

Fig 67. This Hearing Aid uses the 3-transistor DC amplifier covered above, (with some variations).



3 TRANSISTOR SPY AMPLIFIER

Fig 68.

Fig 68. A 3-transistor amplifier operating on 1.5v

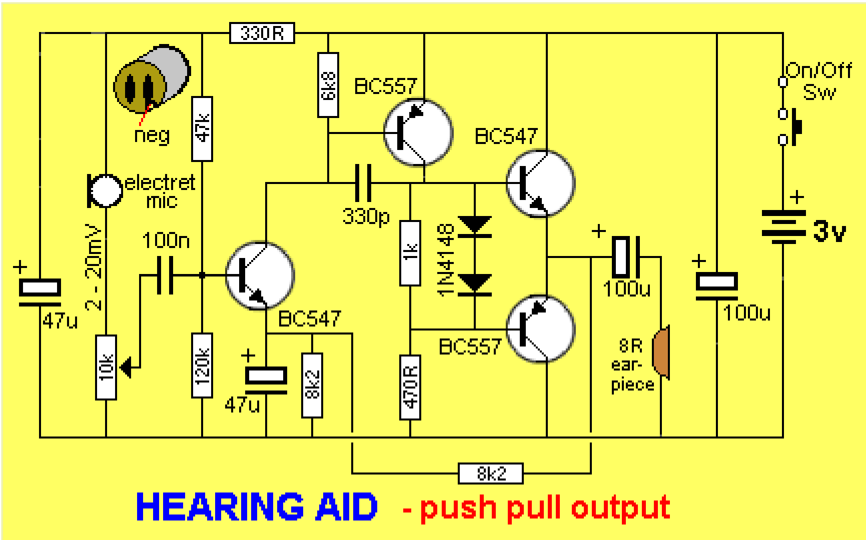


Fig 69.

Fig 69. This Hearing Aid circuit uses push-pull to reduce the quiescent current and also charge/discharge the electrolytic feeding the 8R earpiece.

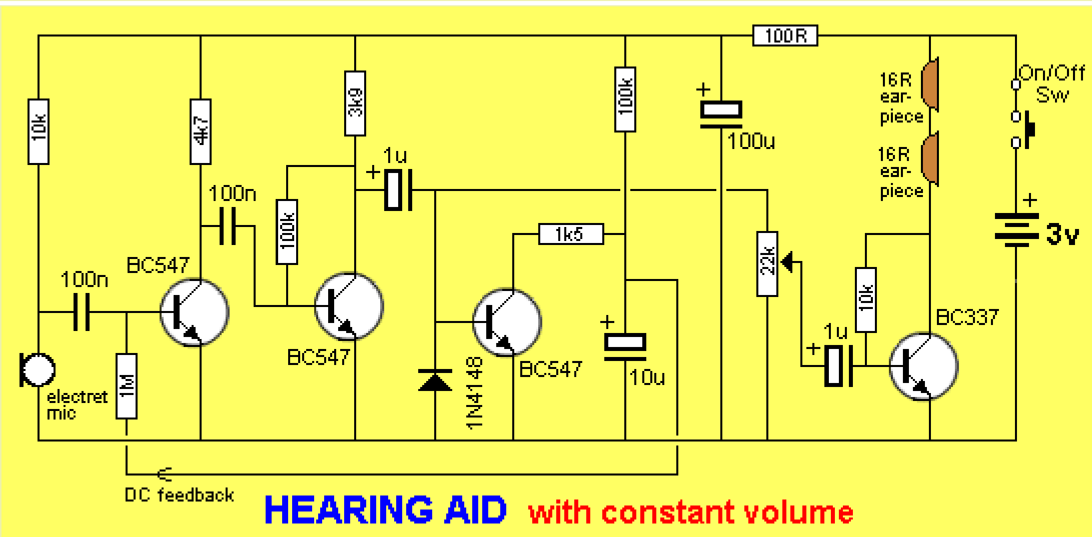


Fig 70.

Fig 70. This Hearing Aid circuit has the first transistor turned on via a 100k and 1M resistors. Connected to this supply is a transistor that discharges the biasing voltage when it sees a signal higher than 0.7v This reduces the amplitude of the signal being processed by the first transistor and produces a constant volume amplifier.

How does reducing the voltage on the base of the first transistor reduce the gain of the first stage?
When the voltage delivered by the 100k and 1M resistors on the base of the first transistor is REDUCED, the current (energy) being delivered to the base is reduced and thus more energy has to be delivered by the 100n capacitor. This causes a larger signal-drop across the 100n coupling capacitor (discussed in Fig 71c below) and thus the amplifier produces a reduced amplification. This is along the same lines as changing from a "Class-A" amplifier to a "Class-C" amplifier (as shown in Fig 107a) where a "Class-C" amplifier gets ALL its turn-on energy from the coupling capacitor.

THE DARLINGTON

There are two types of Darlington transistors. One type is made from two NPN or PNP transistors placed "on-top" of each other as shown in Fig 71 and Fig 71aa:

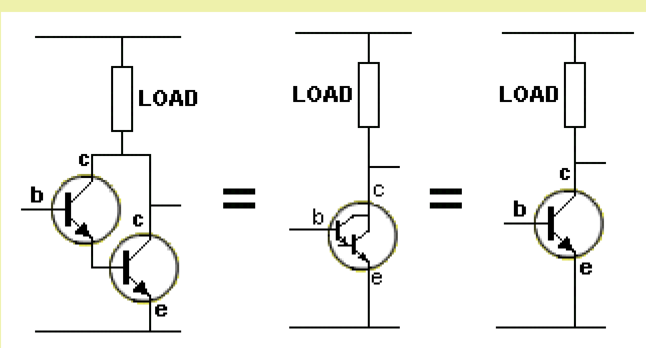


Fig 71.

Fig 71. Two NPN transistors connected as shown in the first diagram are equal to a single transistor with very high gain, called a DARLINGTON.
The second diagram shows the symbol for an NPN Darlington Transistor and the third diagram shows the Darlington as a single transistor (always show a Darlington as TWO transistors.) One difference between a Darlington and a normal transistor is the input voltage must rise to 0.65v + 0.6v5 = 1.3v before the NPN Darlington will turn ON fully.

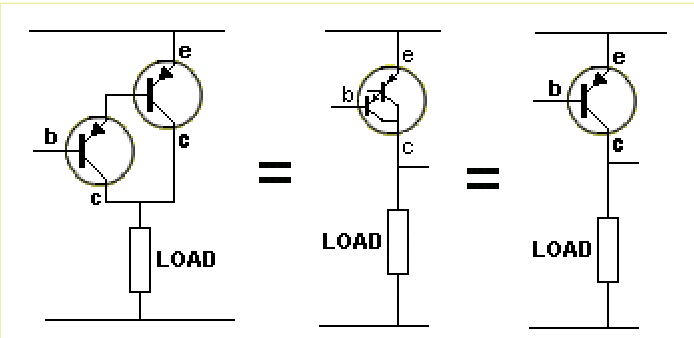


Fig 71aa.

Fig 71aa. shows two PNP transistors connected to produce a single transistor with very high gain, called a PNP DARLINGTON.
The second diagram shows the symbol for a PNP Darlington Transistor and the third diagram shows the Darlington as a single transistor. The input voltage must fall 0.65v + 0.6v5 = 1.3v before the PNP Darlington will turn ON fully.

The other type of Darlington transistor is called the Sziklai Pair. It has an advantage:

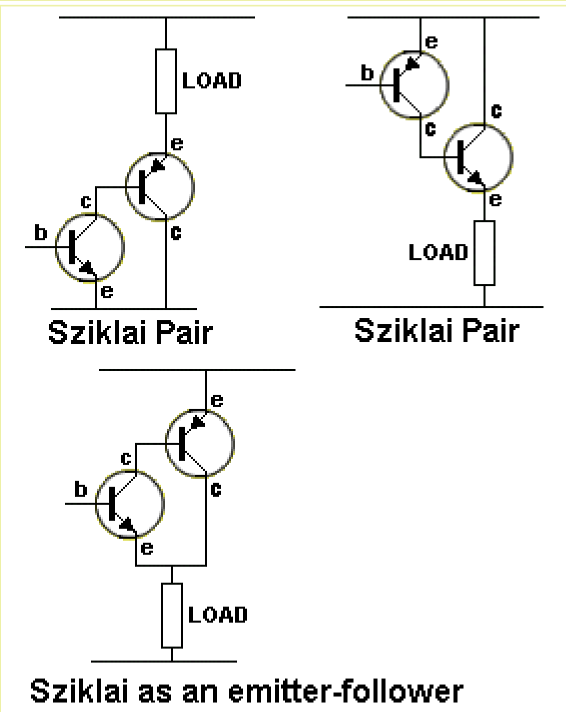


Fig 71ab.

Fig 71ab. shows a NPN and PNP transistor connected to produce a single transistor with very high gain, called a **Sziklai Pair**.
The second diagram shows a PNP and NPN transistor connected to produce a single transistor with very high gain, also called a **Sziklai Pair**. The advantage of this arrangement is the input voltage only needs to be 0.6v5 for the **Sziklai Pair** to turn ON fully.

The **Sziklai Pair** can also be used as an emitter-follower. The output is just 0.65v below the input and the loss across the output transistor is less than 0.5v.

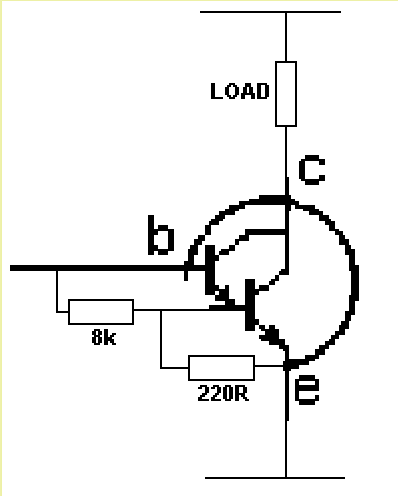


Fig 71aba.

Note: Some Darlington transistors have **inbuilt resistors** and this reduces the input impedance enormously. Two separate transistors in Darlington configuration will have an input impedance of about 300k. The Darlington in the diagram has in input impedance of about 8k.

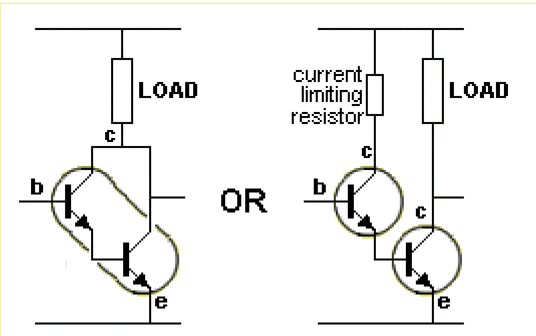


Fig 71abab.

In **Fig 71abab** we have a single Darlington transistor and two transistors in Darlington configuration.
But they do not perform the same in reality.
The difference is most noticeable when the load current is high.

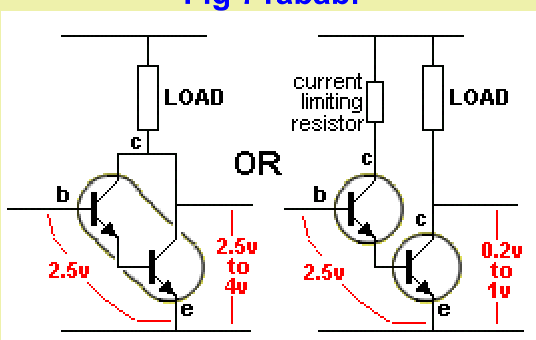


Fig 71abab-1.

Fig 71abab-1 shows the difference. The voltage on the collector of a Darlington transistor will be much higher than a normal transistor (carrying the same current). This is one of the characteristics of a Darlington transistor that has to be recognised.

Fig 71abab-1 shows voltages when the transistors are carrying full current and the different output voltage is considerable.
A Darlington transistor has a much-higher collector-emitted voltage than a normal transistor.

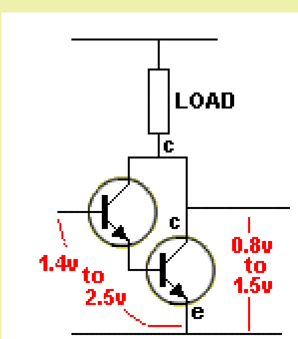


Fig 71abab-2.

Fig 71abab-2 shows voltages when two transistors are connected to produce a Darlington configuration.
These voltages are only approximate but show how the output voltage is created.
This means the load gets pulled down to 0.8v to 1.5v above the 0v rail, for a Darlington configuration, whereas a normal transistor will pull the load down to about 0.2v to 0.5v.
When the current is 1amp to 10amp, this arrangement will have a voltage-drop of about 2.2v to 2.5v and at 10amp, this represents a loss of 25 watts!! **Not a good design**.
All transistors produce different results however the voltage across the Darlington is always higher than the second circuit in **Fig 71abab-1**.
The losses in a Darlington can be as high as 400% more - it all depends on how the two transistors are connected.

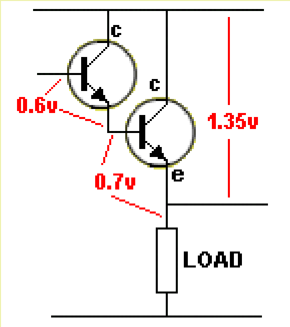


Fig 71abab-3.

Fig 71abab-3 shows voltages when two transistors are connected in Darlington configuration as emitter-followers.
The load loses at least 1.35v and this is considerable when the supply voltage is small.
It also means a lot of heat will be lost in the driver transistor.
This is a very inefficient way to drive a high-power load and should be avoided. (use an NPN common-emitter driving a PNP output transistor as shown in: **The Driver Stage**

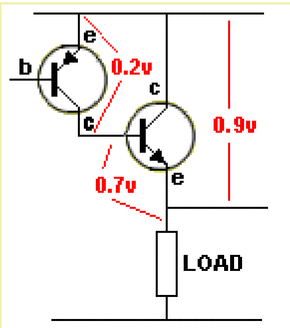


Fig 71abab-4.

Fig 71abab-4 shows two transistors connected as a **Sziklai Pair.**
This produces 0.9v across the output transistor.

THE "SUPER-ALPHA" CIRCUIT

also known as the:

THE "HIGH INPUT IMPEDANCE" CIRCUIT

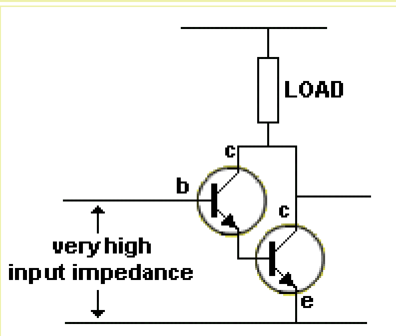


Fig 71abb.

Fig 71abb shows two transistors "on top of each other" **called a DARLINGTON Pair.** This arrangement produces a **very high input impedance** of about 200k and only a very small current is required to produce a "swing" on the output.
The circuit is commonly called a **SUPER ALPHA PAIR** and the input voltage must rise to 0.65v + 0.6v5 = 1.3v before the circuit will start to turn on.
The actual high impedance only occurs when the Darlington pair is just starting to turn on (when the voltage is 1.3v). Below this voltage the impedance is infinite (but of no use). Above 1.3v, the Darlington needs slightly more current and the input impedance is slightly less.

"CURRENT BUFFER" CIRCUIT

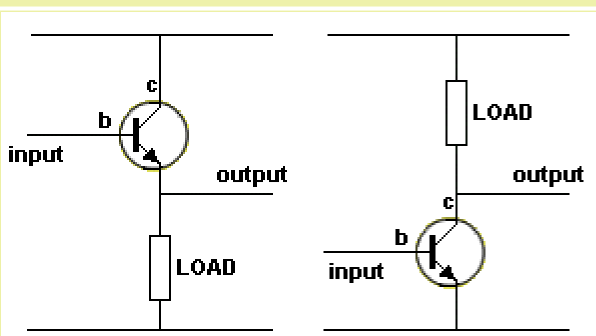


Fig 71abc.

Fig 71abc shows a **CURRENT BUFFER** stage.
Both the **EMITTER FOLLOWER** and **COMMON EMITTER** stages can be used as a **CURRENT BUFFER** and both have the same current amplifying value.
A current buffer simply assumes you have a waveform with sufficient voltage but not enough current to drive a LOAD.
If the **EMITTER FOLLOWER** stage can be connected directly to a previous stage, this makes it the better choice.

"CURRENT SOURCE" CIRCUIT

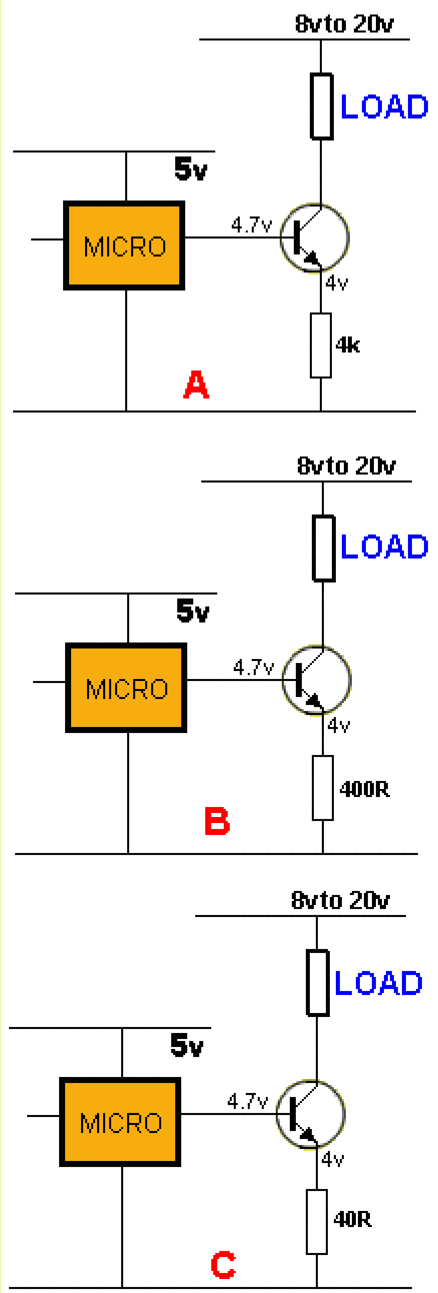


Fig 71abc-1.

Fig 71abc-1 is slightly different to a **CURRENT BUFFER CIRCUIT** (see above) or a **CONSTANT CURRENT CIRCUIT**. This **CURRENT SOURCE** Circuit has some or all the features of the other two circuits but it operates slightly differently and you can use it to deliver a constant current to a load provided the following voltages are provided.

1. In this example, the microcontroller is supplied from a 5v supply, and the output of the microcontroller is 4.7v.

The CURRENT SOURCE circuit uses this 4.7v as a reference and when combined with the resistance of the emitter resistor, a collector current is produced that remains FIXED providing the supply voltage is higher than about 6v and the LOAD accepts the current. The LOAD can be any device that accepts the current and can be a device that would normally take MORE current. In other words the LOAD can be a very low resistance such as a SHORT-CIRCUIT and the current flowing will still be the same as when the previous LOAD is connected. The LOAD can take LESS current but not more.

2. The supply voltage is about 9v to 20v.

The circuit works like this:

Figure **A:** The micro outputs a HIGH and this turns on the transistor.

The LOAD tries to take a lot of current and this current flows through the 4k resistor. When the current reaches 1mA, 4v is developed across the resistor. Suppose the LOAD tries to take more current. A greater voltage will be developed across the resistor and the base-emitter voltage will be less and the transistor will turn OFF slightly. This will reduce the current to 1mA.

For figure **B:** the current flowing through the 400R resistor will be 10mA and 4v will develop across the resistor.

For figure **C:** the current flowing through the 40R resistor will be 100mA and 4v will develop across the resistor.

The supply voltage can be 8v or higher and the circuit will only deliver 100mA.

Very few devices take a constant current however the circuit can be used to deliver a maximum current and protect a project while being tested.

This circuit only works when the load is connected. When the load is removed, the transistor becomes equal to a diode and the output of the microcontroller drives into the emitter resistor as a LOAD via a diode.

"VOLTAGE BUFFER" CIRCUIT

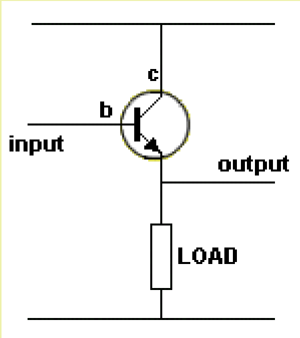


Fig 71abd.

Fig 71abd shows a **VOLTAGE BUFFER** stage. You can also say it is a **VOLTAGE FOLLOWER** as the output voltage follows the input voltage.
You need to define why you need a Voltage Buffer.
In most cases a device (or circuit or stage) will produce a voltage but very little current and if this is connected to another circuit, the output will be reduced (attenuated). To prevent this, an **EMITTER FOLLOWER** can be used as a **VOLTAGE BUFFER** as the output follows the input EXACTLY but 0.6v lower than the input.
The **EMITTER FOLLOWER** stage provides added current so the voltage from the source is not attenuated.

A **Voltage Buffer** and **Current Buffer** circuit can be identical. It's all in the way you describe your requirements.

"VOLTAGE AMPLIFIER" CIRCUIT

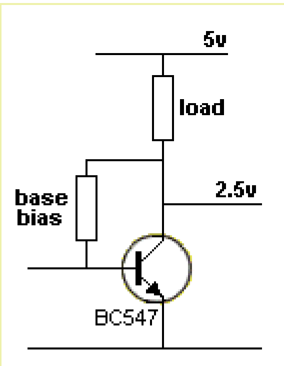


Fig 71abe.

Fig 71abe shows a **VOLTAGE AMPLIFIER** stage. It is really a common-emitter stage with another name. The circuit can have a base-bias resistor or it can be removed.
The actual voltage gain of the circuit is unknown and will depend on the transistor and surrounding components.
However this is a Voltage Amplifier stage and **Fig 71abb** above can also be classified as a Voltage Amplifier.

You can call a circuit by a name that describes what it is doing in a project.

THE BOOTSTRAP CIRCUIT

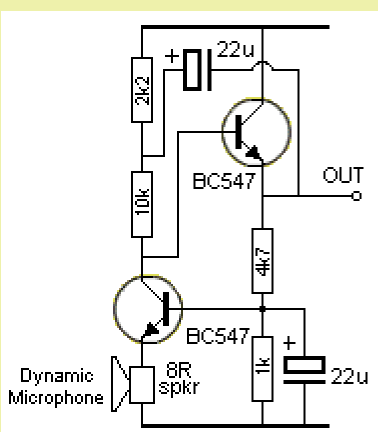


Fig 71ac

Another very interesting circuit is the **Bootstrap Circuit.** It uses positive feedback to achieve very high gain.
The two transistor circuit shown in **Fig 71ac** has a gain of approx 1,000 and converts the very low output of the speaker into a waveform that can be fed into an amplifier.
The circuit is simply a common-base stage and an emitter-follower stage.
But the output of the emitter-follower is taken back to the input of the same stage and this is the Bootstrap feature. It is like pulling yourself UP by pulling your shoe laces.
When the voltage from the speaker reduces by 1mV, the transistor turns ON a little more and pulls the collector voltage lower.
This action takes a lot of effort and to pull it lower, requires more energy from the speaker.
In the Bootstrap circuit, the first transistor pulls the 10k down and this pulls the emitter-follower transistor down. At the same time the 22u is pulled down and it pulls the 10k down to assist the first transistor. In other words the first transistor finds it much easier to pull the 10k resistor down.
When the first transistor turns off, the 2k2 pulls the 10k resistor UP and it is aided by the 22u. The end result is a very high output

voltage swing.

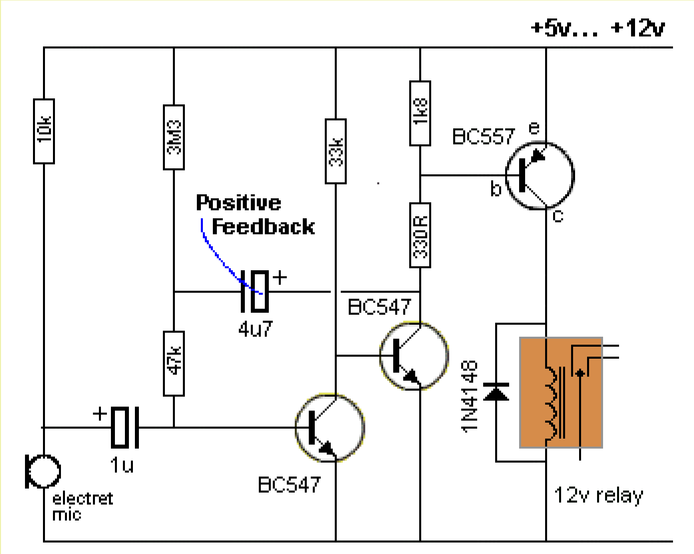


Fig 71acc

Fig71acc shows a **Sound Activated Switch** using a BOOTSTRAP arrangement for the first two transistors.
The first transistor is biased ON via the 3M3 and 47k. This means the collector voltage will be very low and the second transistor will be biased OFF and the third transistor will also be OFF. The relay will not be activated.
When the electret microphone receives audio in the form of a CLAP, the peak will not have any effect on the first transistor as it is already saturated, but the falling part of the waveform will reduce the voltage on the base and allow the transistor to turn off a small amount.

This will turn ON the second transistor and the voltage on the collector will fall.
The 4u7 is connected to this point and it will fall too and reduce the voltage on the base of the first transistor considerably. This will turn the first transistor off more and the process will continue and turn on the relay.
But during this time the electrolytic is discharging, then charging via the 3M3 and eventually it charges to a point where the base of the first transistor sees a voltage above 0.7v and it is turned on again.
The collector voltage of the second transistor rises and this turns on the first transistor fully and the two transistors swap states. The relay turns off.
If the microphone continues to produce negative (or falling waveforms), the relay will continue to remain energised.
The 4u7 has the effect of a "snap action" where the circuit very quickly changes from one state to the other. It is very similar to the action you get with a SCHMITT TRIGGER.
This circuit is not a LATCH. The relay does not stay energised. It is only energised for a short period of time.

Fig 71acc is an example of **POSITIVE FEEDBACK**

There are two types of FEEDBACK. Positive and Negative.
Positive feedback delivers a signal that makes the circuit produce a larger signal. This feedback may be in the form of a signal that moves in the negative direction. We are not talking about the signal being in the positive or negative direction, we are talking about the **effect** it has on the circuit.
Negative Feedback is where the signal passes back to a previous stage to reduce the amplitude of the signal. In most cases the feedback signal has a greater effect on the peaks (and troughs) and these normally represent noise or distortions in the signal. In this way the quality of the signal is improved.

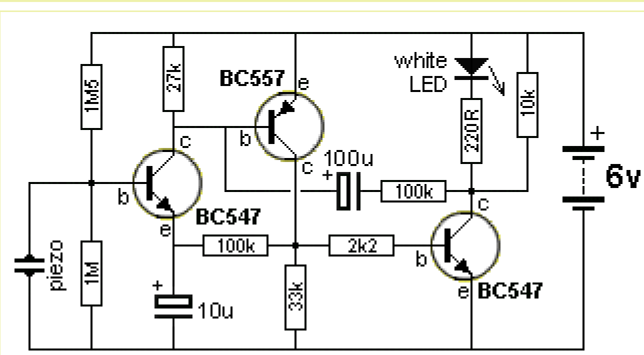


Fig 71acd
Clap Switch with 15-second Delay

Fig71acd shows a 3 transistor circuit using a piezo diaphragm to detect the noise of a clap. The first two transistors form a high-gain amplifier, studied in **Figs 40 & 40a**.
The voltage across the 33k resistor is kept below 0.7v by adding the 1M5 and

Designed 12-11-2011 - C Mitchell

1M voltage-dividing resistors to the base of the first transistor and this sets the voltages for the first two transistors.
The sound of a clap produces a waveform across the 33k to turn on the third transistor and this pulls the 100u down via the 100k, to turn ON the BC557.
This keeps the 2nd and third transistors turned ON and illuminates the LED for about 15 seconds.

The 100u charges via the 100k and the emitter-base junction of the BC557 and initially this current is high. But gradually the 100u becomes charged and the current-flow reduces and eventually the BC557 cannot be kept ON.
It turns OFF and the third transistor turns OFF too.
The negative end of the 100u rises and takes the positive end slightly higher too. The 100u discharges through the 27k, 100k and 10k resistors. The circuit takes about 20 seconds to reset after the LED goes out. During this time the circuit will not respond to another clap.
The quiescent current is about 20uA, allowing 4 AA cells to last a long time.
This circuit is very clever in that it uses the middle transistor TWICE. It is equivalent to having 4 transistors.
The first two transistors form a high-gain amplifier and the middle and third transistors form a delay-circuit using a BOOTSTRAP arrangement discussed above.
As we mentioned at the beginning of this eBook, three directly-coupled transistors can produce an enormous gain and you have to be very careful that unwanted feedback (sometimes called motor-boating) does not occur. We have avoided this by keeping the voltage across the 33k below 0.6v so the third transistor is only turned ON when noise is detected. The second and third transistors then turn into a switch to keep the LED illuminated and the 100u creates a time-delay.

THE "LOW IMPEDANCE" CIRCUIT (stage)

A circuit or "stage" can be classified as LOW IMPEDANCE. This can refer to its INPUT IMPEDANCE or its OUTPUT IMPEDANCE or BOTH.
We have already covered this type of circuit but have not specifically referred to it as LOW IMPEDANCE.
Low Impedance generally refers to a component on the input or output that is less than 500 ohms.
The circuit can also be called "Impedance Matching" or a "Driver Stage" and the following two circuits can be classified as "**Low Impedance**:"

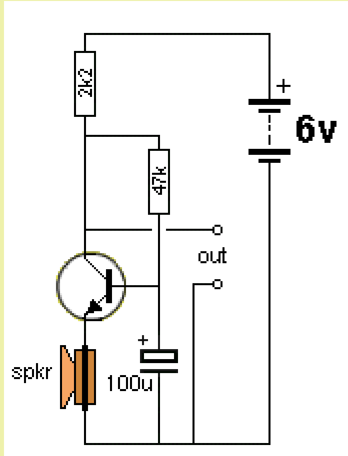


Fig 64.

The input impedance of the common-base stage is very low.

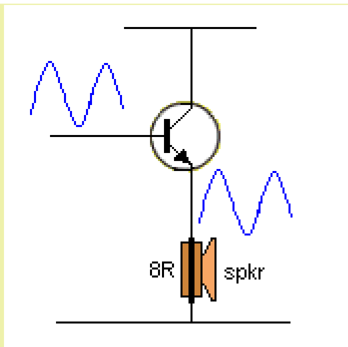


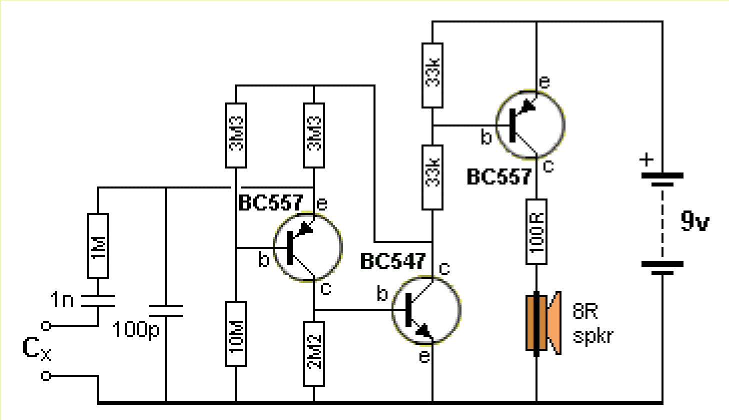
Fig 64aa.

The output impedance of the emitter-follower stage is very low. The input impedance is 100 times greater than the output. 100 x 8R = 800R. The input impedance can also be classified as LOW IMPEDANCE.

A low-impedance circuit (such as Fig 64) can employ non-screened, long leads between the speaker and input of the circuit without the problem of noise, hum or spikes being picked up.
This is one of the reasons for using a low-impedance circuit. It does not pick up noise. The reason it does not pick up noise is this: Noise consists of high-voltage spikes that have low current. This type of waveform does not have the "strength" to raise and lower the signal on a low-impedance input and thus it does not appear on the input.

THE "HIGH IMPEDANCE" CIRCUIT (stage)

A circuit or "stage" can be classified as HIGH IMPEDANCE. This can refer to its INPUT IMPEDANCE or its OUTPUT IMPEDANCE or BOTH.
High Impedance generally refers to a component on the input or output that is higher than 1M or a set of components that cause the transistor to take very little current. This type of circuit is very unstable and prone to interference and noise and spikes from external sources. In addition, the voltages on the transistor will change with temperature and the gain of the transistor.
The following circuit has very high value resistors on the first transistor and this allows it to detect very small changes in voltage due to very small changes in current-flow in the components in the circuit.

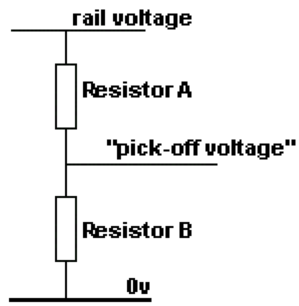


CAPACITOR TESTER

The first two transistors form a very high-gain amplifier. If the 100p is removed, the circuit will not work. If a capacitor is placed on the base of the first transistor, the circuit will not work. The circuit must be kept as shown.
The first two transistors form a very unusual "feedback-oscillator."
The circuit is not really an "oscillator" but a circuit with high instability. It's the same instability as "motor-boating" or "squeal." The feedback is the 3M3 on the base of the first transistor. It delivers the signal from the output to the input. The circuit needs "noise" to start its operation and it can sit for 5 seconds before self-starting.
Let's look at how the two transistors are connected. They are directly connected (called DC connection) and this forms a circuit with very high gain (about 250 x 250 = about 60,000). Transistors can achieve very high gain when lightly loaded. Both transistors are arranged as common-emitter amplifiers.
Here is the amazing part of the circuit. The 100p is acting as a miniature rechargeable battery. It takes time to charge and discharge and produces the timing (the frequency) for the oscillator.
To start the discussion we consider the 100p is holding the emitter of the first transistor "rigid." This makes it a common-emitter stage for a PNP transistor.
The transistor will produce a very small amount of junction-noise and because the 2M2 collector-load is such a high value, the noise will be passed to the base of the second transistor. We will assume the first transistor turns ON a small amount due to this junction-noise. This will make the collector voltage rise and this will be passed to the base of the middle transistor.
This will turn on the middle transistor and the voltage on the collector will fall. The base of the first transistor is connected to this via a 3M3, and the base voltage will fall.
The emitter is being held "up" by the 100p and because the base-voltage drops, the transistor turns on more. It gets current to turn on from the energy in the 100p and this allows the middle transistor to turn ON more. This action continues with both transistors turning ON more and more.
The energy to keep the transistors turning ON comes from the 100p and the voltage on this capacitor drops. Eventually the voltage falls to a point where the first transistor cannot supply energy to the base of the second transistor and the collector voltage rises. This makes the base of the first transistor rise and it gets turned off a small amount. This action turns off the middle transistor slightly more and eventually they are both turned off. The 100p is charging during this time via the 3M3 and eventually the emitter rises to a point where the first transistor gets turned ON a small amount to start the next cycle.

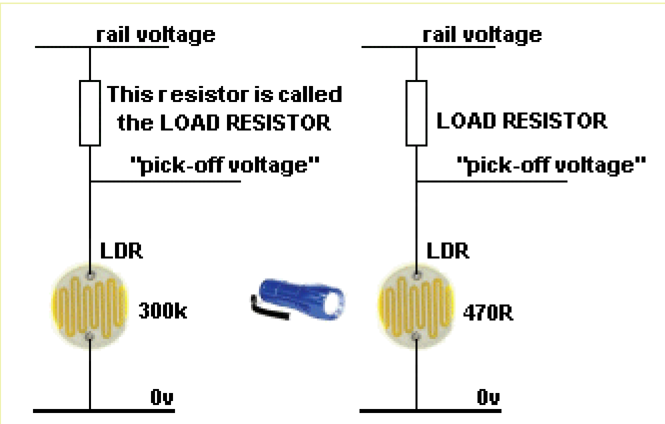
There are a couple of features you have to understand with this circuit, (the first transistor) because it uses very high value resistors.
1. The feedback signal will pass through the 3M3 resistor to the base of the first transistor with very little attenuation (reduction) because the base presents a very high impedance due to the fact that the transistor is very lightly loaded and the base requires very little current.
2. Normally a 100p could not be used to create an audio frequency as it provides very little energy and be able to only produce a very high frequency. But when the timing resistor is a very high value (in this case the 3M3 on the emitter) it will take a long period to charge and discharge and an audio frequency can be obtained.
The 100p sees a waveform of nearly 7v during its charge and discharge cycles.

THE VOLTAGE DIVIDER

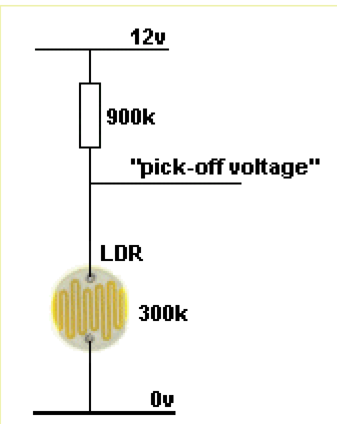


A voltage divider consists of two resistors and a "pick-off"

We have covered many circuits and one question you will be asking is: "How do you select the resistor for the collector load?" or "Why is the voltage on the collector equal to half-rail?"
The answer comes under the heading: **VOLTAGE DIVIDER.**
When two equal resistors are placed in series, the voltage at their join is equal to half the rail voltage. But if the values are different, the voltage is either higher or lower. The circuit is still called a VOLTAGE DIVIDER.
The **load resistor** is one resistor and the **transistor** is the other resistor. But the other resistor does not have to be a transistor, it can be a relay, globe, motor or Light Dependent Resistor.



We will take the simple case of a Light Dependent Resistor (**LDR**).
The LDR we are using is 300k in the dark and 470R when fully illuminated.
An LDR must be connected in series with a resistor to create a circuit called a **VOLTAGE DIVIDER** so the voltage at the join of the two components can be connected to a detecting-circuit. This voltage is called the "**pick-off**" voltage. The detecting-circuit in this case needs to see about 8v when the LDR is not illuminated and about 1v when illuminated.

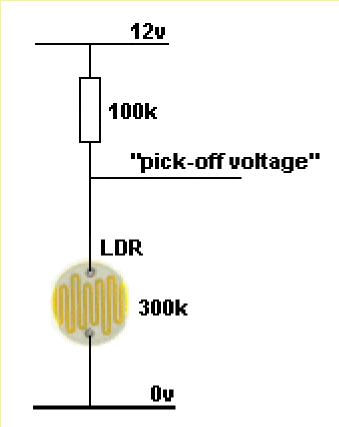


Let us select 900k for the **LOAD RESISTOR**. The voltage at the join will be 3v when the **LDR** is not illuminated.
Here's how to work it out:
(we have selected values for easy calculating.) The total resistance is 1,200k This means each 100k will have 1 volt across it.
This means 300k will have 3v across it and
900k will have 9v across it.

The resistance of the load resistor is too high.

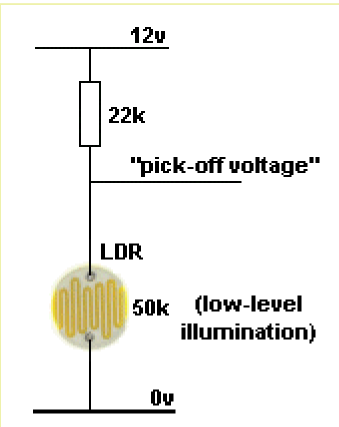
Choose 100k.

See next diagram . . .



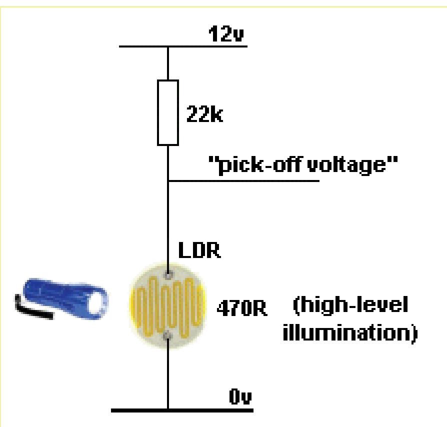
Using 100k load resistor. The voltage at the join will be 9v.
Here's how to work it out:
The total resistance is 400k. Each 100k will have 3v across it. The "pick-off" voltage will be 9v when the LDR is not illuminated. .
But if the LDR sees a low level of illumination in a normally-lit room, its resistance will be about 50k, so we need to change the values to reflect this.

See next diagram . . .

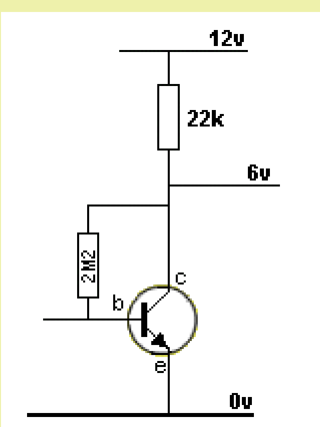


Choose 22k for the LOAD RESISTOR.
The voltage at the join will be about 8v when the LDR is faintly illuminated.
This is called a "realistic assessment."   You have to consider a small amount of light will be present in a normal environment and this will reduce the resistance of the LDR from 300k to about 50k.

Now we will determine the "pick-off voltage" when the LDR is brightly illuminated from say a torch.



The voltage at the join will be about 0.5v when the LDR is fully illuminated.
The 22k load resistor produces the required 8v and 1v values for the "pick-off' voltage.



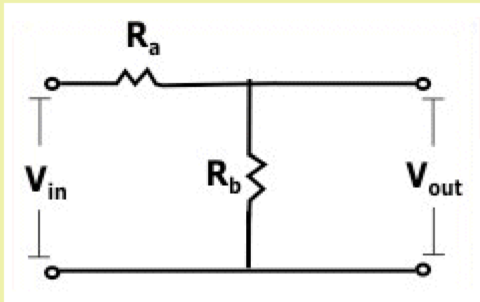
The same **VOLTAGE DIVIDER** principle applies to this transistor stage.
The transistor and 2M2 are effectively equal to 22k since the "pick-off voltage" is half rail voltage.
When the collector voltage sits at half-rail, the signal can extend in the positive direction and negative direction by the maximum amount.
To achieve mid-rail voltage, the base-bias resistor is selected to get 6v on the collector.
There is no formula to achieve mid-rail voltage as it will depend on the gain of the transistor and most of them come from a batch with a wide range of values. Simply select a base-bias resistor that provides half-rail voltage.
The stage is classified as a **self-biased stage** as a capacitor is added to the input and output, when the stage is added to a circuit.

The voltage at the join of two equal resistors is half-voltage, but if the resistors are different-

value, the voltage needs to be calculated. Here is a calculator:

Voltage Divider Resistance Calculator

Enter any of the three values, and then click the Calculate button.



V_{in} = Input voltage
V_{out} = Output voltage

Input voltage V_{in}:	V
Resistance R_a:	Ω
Resistance R_b:	Ω
Output voltage V_{out}:	V

Reset

On the next page we continue our coverage of the transistor (called a Bipolar Junction Transistor - BJT or "normal" or "standard or "common transistor") in amplifying circuits, including oscillators . . .

P2

The Transistor Amplifier

FET DEVICES

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THE FET

The **Field-Effect Transistor** is just like the ordinary transistors we have studied.
It has three leads and is connected just like an ordinary transistor.
The only difference is the name of the leads and the voltage on the "base."
The "base" is now called the "GATE" and nothing happens on the GATE until a higher voltage is reached.
The voltage on the BASE of an ordinary transistor needs to be 0.55v before the transistor starts to conduct and at 0.7v it is fully turned **ON** (can be up to 0.9v).
For a FET, the voltage on the **GATE** is **HIGHER**. It needs to be 3.5v for some FETs and as high as 6v for others.
There are two other slight differences between a FET and an ordinary transistor:
The voltage on a FET does not need any current. For an ordinary transistor, CURRENT is needed into the base and the transistor will amplify this about 100 - 200 times to produce collector current.
Since **NO CURRENT** is needed on the **GATE** of a **FET**, the current through the source-drain can be as high as the device will allow. This is the first advantage of a FET.
There is a very small "gap" or "range" where the voltage on the GATE starts to turn the FET **ON** (from zero output current; **gradually,** to full output current) and if you work in this range, the FET becomes an audio amplifying device - linear amplifying device.
Every FET is different and the voltage range is quite considerable.
Refer to the following data sheet. The red frames contain the data for the voltage on the gate to turn the FET on. These voltages are only a guide and you need to build a circuit and test the device to determine the actual values:

FETS

		BVgss		Vgs (off)				Idss (mA)				YFS (umhos)			Ptot	
Type	Case	V	@ Ig (uA)	Min	Max	@ Vds	Id (nA)	Min	Max	@ Vds	Vgs	Min	Max	@ Vds	mW	Use/Comments
BF245B	TO-92 Var 1	30	1	0.5	8	15	10	6	15	15	0	3000	6500	15	300	N/CH Junction audio to H.F.
BF981	SOT-103	>6		2.5		10	20A	4	25	10	0		14000 typ.		225	N/CH Dual gate MOS. VHF AMP.
BF998	SMT	>6	±10		2.5	8	20mA	2	18	10	0/4		24000 typ.	8	200	N/CH VHF/UHF dual gate SMT
BFR84	TO-72(2)	>6	100	1.5	3.8	10		20	55	10	0		15000 typ.	10	300	N/CH VHF dual gate
MFE131	TO-72(2)	±6	±10		4	15	200mA		30	15	0	8000	20000	15	300	N/CH Dual gate MOS. VHF amp.
MPF102	TO-92(72)	25	10	0.5	8	15	2	2	20	15	0	2000	7500	15	310	N/CH Junction – VHF
MPF105	TO-92(72)	25	1		8	15	10	4	16	15	0	2000	6000	15	310	N/CH Junction – audio Sw.
MPF106	TO-92(72)	25	1	0.5	4	15	10	4	10	15	0	2500	7000	15	310	N/CH Junction – RF
MPF131	2&2	±6	±10		4	15	200mA	3	30	15	0	8000	20000	15	350	N/CH Dual gate MOS. VHF amp
2N4342	TO-92(72)	25	10		5	10		12	30	10	0		6000	10	180	P/CH Junction – audio Sw.
2N5245	TO-92(77)	30	1	1.5	6	10		1	18		0		5800 typ.	10	360	N/CH VHF/UHF MIXER
2N5247	TO-92(72)	25	10	0.5	6	15	10	1	5	15	0	1000	5000	15	625	N/CH Junction – audio Sw.
2N5459	TO-92(72)	25	1	2	8	15	10	4	9	15	0	2000	6000	15	310	N/CH Junction – audio Sw.
2N5484	TO-92(72)	25	1	0.3	3	15	10	1	5	15	0	3000	6000	15	310	N/CH Junction – VHF
2N5485	TO-92(72)	25	1	0.5	4	15	10	4	10	15	0	3500	7000	15	310	N/CH Junction – VHF
2N5486	TO-92(72)	25	1	2	6	15	10	8	20	15	0	4000	8000	15	310	N/CH Junction – VHF
3SK40	TO-72(2)	±6	±10		4	15	200mA		25	15	0	8000		15	250	N/CH Dual gate MOS. VHF amp.
3SK121	2-6F1A	–5		–2.5	4	5	100mA	20	45	5	0		17000 typ.	10	200	N/CH UHF GaAs dual gate

POWER FETS

Type	Case	Ptot (W)	Vds (Max) (V)	Id (Max) (A)	Vgs (thres.) Min	Vgs (thres.) Max	Gfs umhos	Ciss (pF)	Rds (ohms)	Comment
BUK456-60A	TO-220	150	60	52	2.1	4	17M	2000	0.028	Inverters
BUK457-600B	TO-220	150	600	7.1	2.1	4	8M typ.	1800	1.2	Mains SMPS
BUZ71A	TO-220	40	50	13	2.1	4	4M	600	0.12	Nch power MOSFET
IRF520	TO-220	60	100	9.2	2.0	4	4M	350	0.25	Nch power MOSFET
IRFP450	TO-247	180	500	14	2.0	4.0	14m	2700	0.4	Nch power MOSFET
MTP3055E	TO-220	40	60	12	2.0	4.5	4M	500	0.15	Nch power MOSFET
PHP6N60E	TO-220	125	600	6.5	3.0	4.0	5m	1500	1.2	Nch power MOSFET
VN10K	TO-92(76)	1	60	0.3	0.3	2.5	100K	48	5	Nch DMOS FET
VN88AF	TO-202F	12.5	80	2	0.8	2				Nch VMOS FET
2SJ48	TO-3	100	120	7	0.15	1.45	1M	900	1	Pch power MOSFET
2SJ49	TO-3	100	140	7	0.15	1.45	1M	900	1	Pch power MOSFET
2SJ162	TOP-3	100	160	7	0.15	1.45	1M	900	1	Pch power MOSFET
2SK133	TO-3	100	120	7	0.15	1.45	1M	600	1	Nch power MOSFET
2SK134	TO-3	100	140	7	0.15	1.45	1M	600	1	Nch power MOSFET
2SK1058	TOP-3	100	160	7	0.15	1.45	1M	600	1	Nch power MOSFET
60N06	TO-220	150	60	60	2.0	4.0	20M	1950	0.014	Nch power MOSFET

click image for enlarged view

However the FET has high losses when operating in this linear mode and the current it can handle is limited.
When a FET is used in **SWITCHING MODE** (called **Digital Mode**) the losses in the FET are minimal and the device can handle very high currents.

The second advantage is the voltage-drop across the **DRAIN-SOURCE** terminals is very low and this means very little heat is generated (lost) in the device and they can deliver (handle) a very high current.

If you think of a FET along these lines, you will not be "mystified." (If you can achieve the relatively high input voltage needed, you can use a FET.)

Here is a more-technical description of a FET:

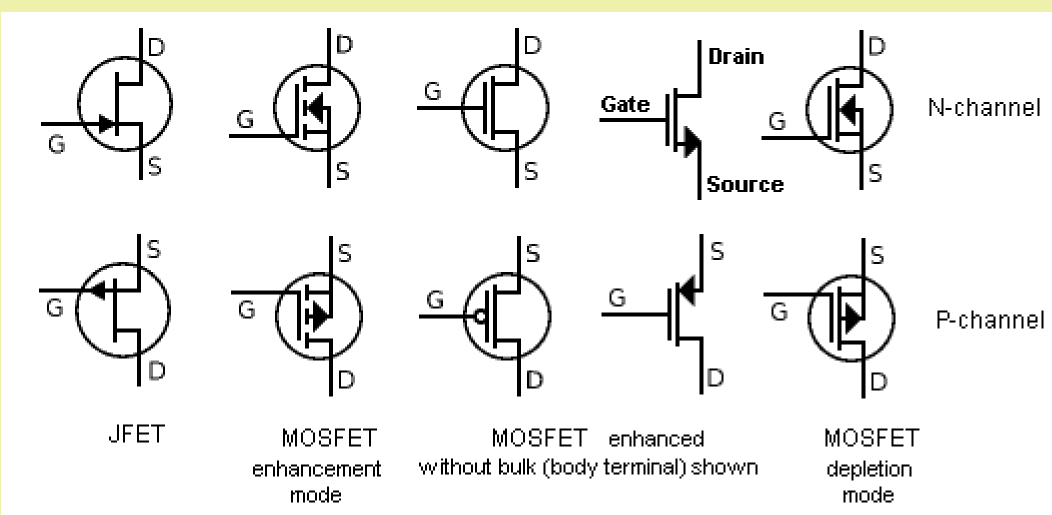
The **Field-Effect Transistor** provides an excellent voltage gain with the added feature of a high input impedance. There are also low-power-consumption configurations with good frequency range and minimal size. JFETs, depletion MOSFETs, and MESFETs can be used to design amplifiers having similar voltage gains. The depletion MOSFET (MESFET) circuit has a much higher input impedance than a similar JFET configuration.

Whereas a **BJT** device controls a large output (collector) current by means of a relatively small input (base) current, the **FET** device controls an output (drain) current by means of a small input (gate-voltage) voltage. In general, therefore, the BJT is a *current-controlled* device and the FET is a *voltage-controlled* device. In both cases, however, the output current is the controlled variable. Because of the high input characteristic of FETs, the ac equivalent model is somewhat simpler than that employed for BJTs.
Whereas the BJT has an amplification factor, β (beta), the FET has a transconductance factor g_m.

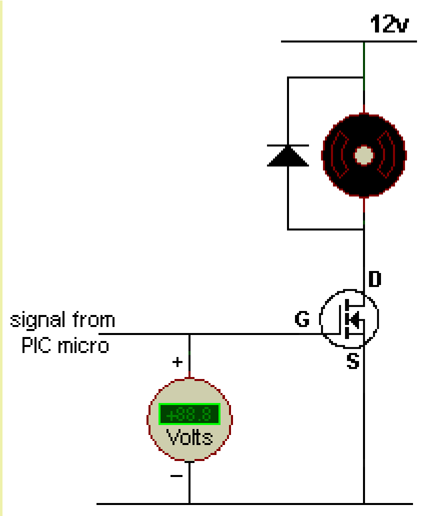
The FET can be used as a linear amplifier or as a digital device in logic circuits. In fact, the enhancement MOSFET is quite popular in digital circuitry, especially in CMOS circuits that require very low power consumption. FET devices are also widely used in high-frequency applications and in buffering (interfacing) applications.

Although the common-source configuration is the most popular, providing an inverted, amplified signal, common-drain (source-follower) circuits providing unity gain with no inversion and common-gate circuits providing gain with no inversion. Due to the very high input impedance, the input current is generally assumed to be 0µA and the current gain is an undefined quantity. Whereas the voltage gain of an FET amplifier is generally less than that obtained using a BJT amplifier, the FET amplifier provides a much higher input impedance than that of a BJT configuration. Output impedance values are comparable for both BJT and FET devices.

A MOSFET is a transistor. It is a **Metal Oxide Field Effect Transistor.**
Here are the symbols for FETs and MOSFETs:

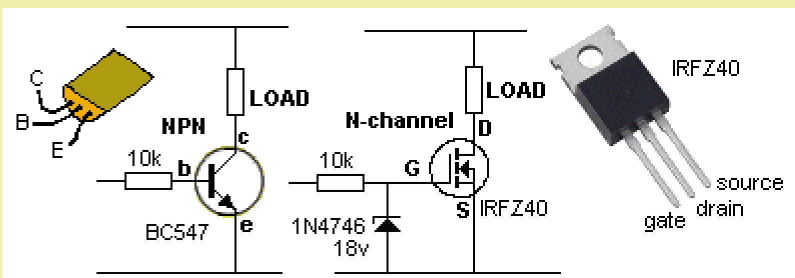


Here is an animation showing how to turn on an N-channel MOSFET:



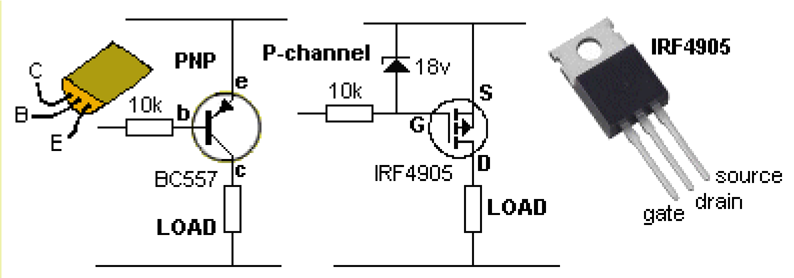
MOSFET turns ON when gate-to-source is more than about 2v (2v to 5v)

The easiest way to understand how MOSFETs work is to compare them with PNP and NPN transistors and show them in similar circuits. The advantage of a MOSFET is this: It requires very little current (almost zero current) into the gate to turn it ON and it can deliver 10 to 50 amps or more to a load.
A MOSFET can be used in place of an ordinary transistor (called a bipolar junction transistor, or BJT) providing one slight difference is taken into account.
An ordinary NPN transistor will turn ON when the base voltage is about 0.65v more than the emitter but a MOSFET needs the gate terminal to be at least 2v to 5v, (depending on the type of MOSFET) above the source voltage.
Here is a comparison between an NPN transistor and N-channel MOSFET:



A zener must be added to the gate of a MOSFET if the gate voltage comes from a supply that is above 20v.
A normal transistor is a current amplifying device.
For a load current of 100mA, the base current for a BC547 will need to be about 1mA.
This means it has a current gain of about 100.
A MOSFET is a voltage controlled device and the current it will handle depends on its physical size and the way it is constructed. You cannot change this parameter.
For a load current up to about 35Amp, the gate current for a IRZ40 will be less than 0.25mA. When the gate voltage is 3v to 4v higher than the source, it turns on and the resistance between source and drain terminals is about 0.028 ohms. It will handle up to 35 amps.
The load determines the current through the MOSFET (not the MOSFET) and if it is less than 35 amps, a IRFZ40 is suitable for the application.

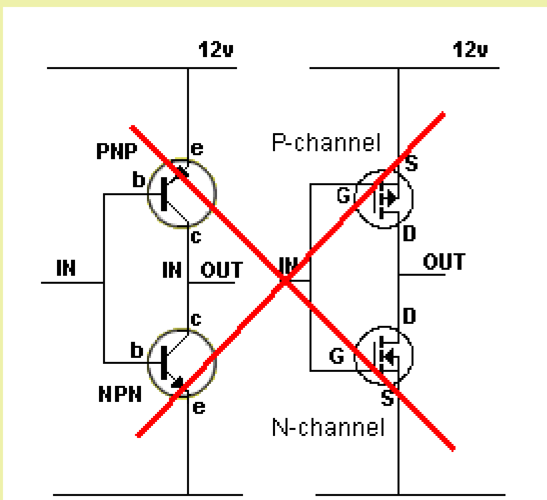
Comparison between a PNP transistor and P-channel MOSFET:



When the gate voltage is 4v LOWER than rail voltage, the MOSFET turns ON. The 10k resistor on the base of the transistor is needed to prevent the base current exceeding the amount of current needed by the transistor to deliver current to the load. However the 10k resistor on the gate of the MOSFET is not needed. Providing the voltage (up to 18v) on the gate rises and falls quickly, the MOSFET will not get hot. The critical period of time is the 0v to 3v section of the waveform as this is when the MOSFET is turning on.

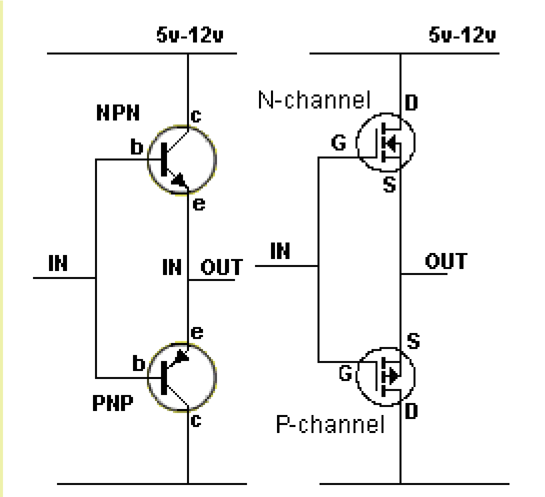
PUSH PULL

MOSFETs can be placed in push-pull mode, just like PNP and NPN transistors.
They must be connected correctly to prevent damage.
In the following circuit you can see the transistors and MOSFETs have been connected incorrectly.
For the PNP/NPN transistor circuit, as the input changes from high to low or low to high, both transistors are turned on during the transition. Only one transistor is turned on when the line is high and only the other transistor is turned on when the line is low, but during the transition, BOTH are turned on.
The same applies with the MOSFETs. When the input is at mid-rail, a voltage between gate and source will be produced for both MOSFETs. Since a MOSFET can handle many amps, this will put a short-circuit across the power rail and will cause a lot of damage.



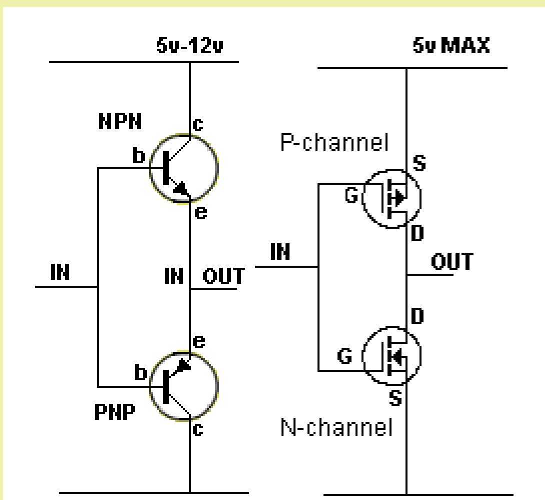
Transistors and MOSFETs will produce short-circuit

The correct placement for the NPN and PNP transistors is shown in the diagram below. The output will rise and fall in harmony with the input, however there will be a small 1v2 gap at mid-rail where the output will not respond as this represents 0.6v for the base-emitter voltage of each transistor. You should not connect two MOSFETs as shown the gap will be 6v as the gate to source voltage for each transistor is about 3v, but you cannot connect the gates of the two MOSFETs because each MOSFET will turn off when the gate-to-source voltage is less than about 3v across these two terminal. This means the output will be 3v less than rail voltage and not go below 3v above 0v rail. Both MOSFETs will not turn on during any part of the cycle and no short circuit will occur, but the output will be less than full rail-voltage swing and the MOSFETs are not being supplied with a gate-to-source voltage that has a guaranteed fast rise and fall time (and the MOSFETs may heat up). This is an unreliable design.



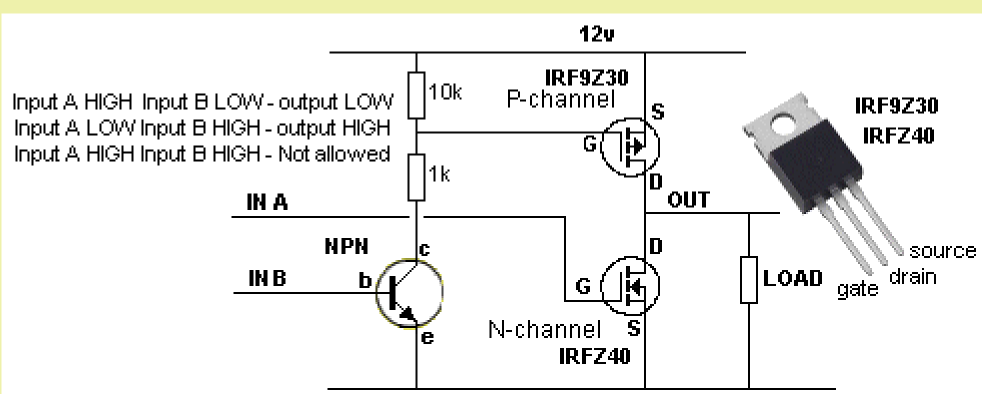
MOSFET output is less than rail voltage

The solution is shown in the diagram below. The transistor configuration will work on ANY rail voltage but the MOSFET "totem-pole configuration" will only work up to 5v. This is due to the characteristics of a MOSFET. The MOSFETs used in this arrangement have a gate-to-source characteristic of slightly more than 3v and do not turn on when the voltage across these two terminals is 3v. This means the supply can be 6v and when the input is at mid-rail, 3v will be across each gate-to-source and neither will be turned on. That's why TTL logic is limited to 5v operation. The output will be extremely close to **rail-to-rail** for the MOSFET configuration.



Max voltage for MOSFET arrangement is 5v

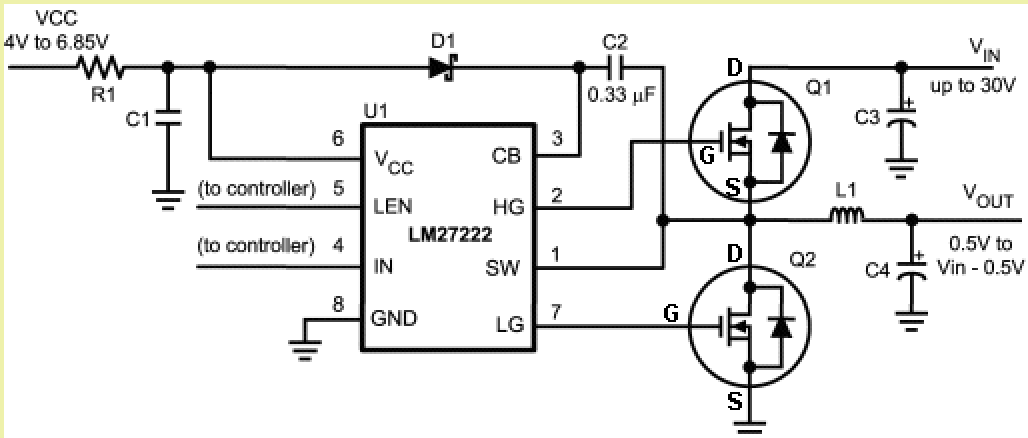
For a supply greater than 5v, a different MOSFET configuration must be used to get full rail-to-rail output. The MOSFETs must be turned on individually.



PUSH-PULL USING MOSFETS

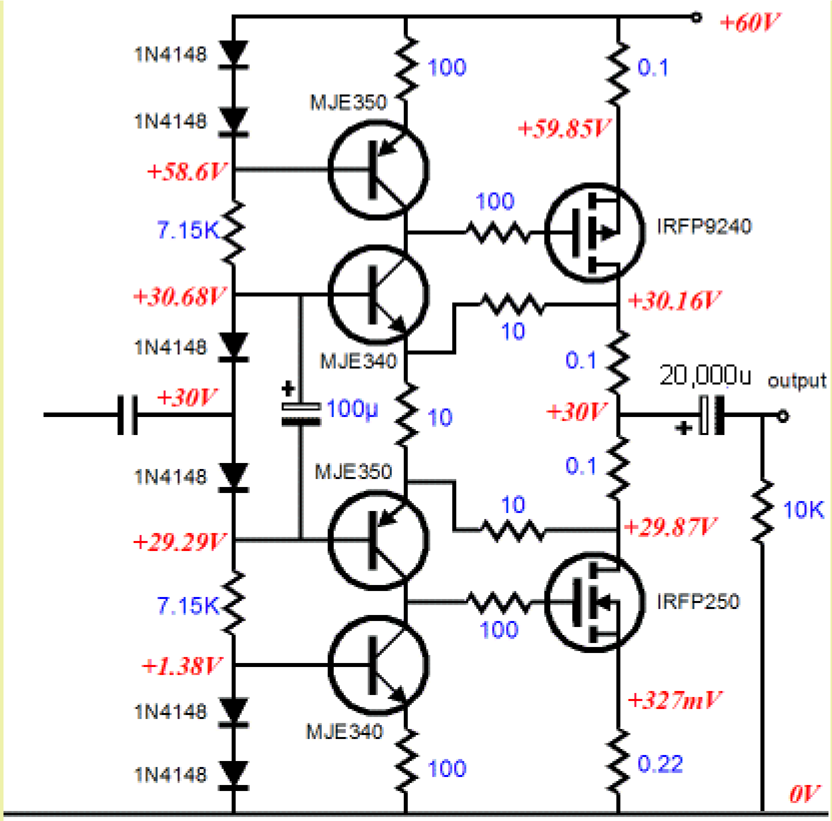
PUSH PULL USING MOSFETS

The circuit above sinks up to 35A via the N-channel MOSFET and delivers about 18Amp via the P-channel MOSFET. **Input A** must rise quickly to prevent the MOSFET heating up during the turning-on period. **Input A** must rise to at least 4v to guarantee the MOSFET turns ON.
Input B must rise above 0.65v to turn the transistor ON. The voltage on the collector of the transistor will fall and this will provide a gate-to-source voltage for the P-channel MOSFET.
Both inputs must not be HIGH at the same time as this will turn ON both MOSFETs and create a short-circuit on the power rail.



The circuit above is much more complex than meets the eye.
To turn on the top N-channel MOSFET, the gate must be taken at least 3v higher than the source because it is a SOURCE FOLLOWER (similar to an EMITTER FOLLOWER). This is equal to Vin + 3v.
How does pin HG get this high voltage?
It gets it from a voltage doubling circuit made up of the 0.33u, high speed diode D1 and an oscillator in the chip.
The circuit is a buck converter and will reduce any supply voltage to a lower voltage with very high efficiency. It allows a small "packet of energy" to flow to the Vout terminal via the inductor L1 and this percentage determines the Vout voltage.

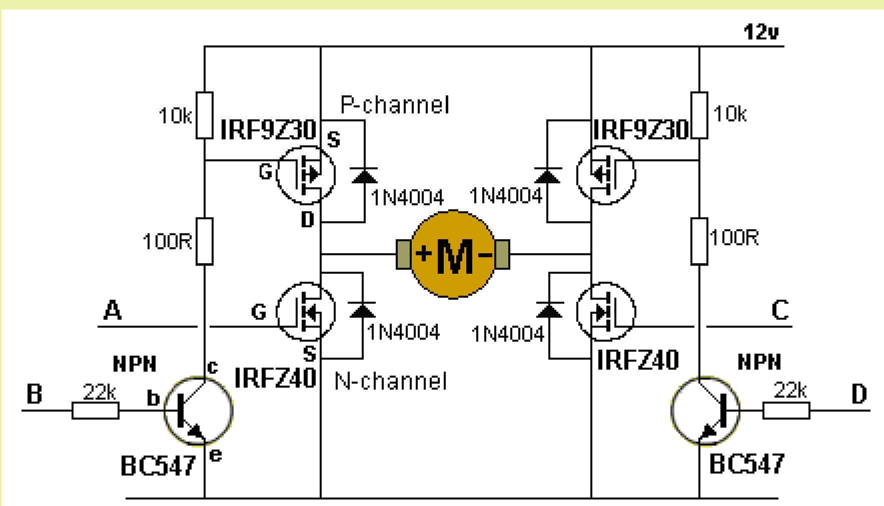
Here is an audio amplifier using PUSH PULL mode to drive a speaker:



The top two transistors are in push-pull mode to turn the P-channel MOSFET on and off very quickly. They speed up the incoming waveform and prevent the MOSFET generating heat during the turning-on process.
The two lower transistors do the same thing.
The diodes and resistors connected to the input form a voltage-divider to correctly bias the push-pull transistors.

H-BRIDGE

An H-Bridge can be designed using MOSFETs:

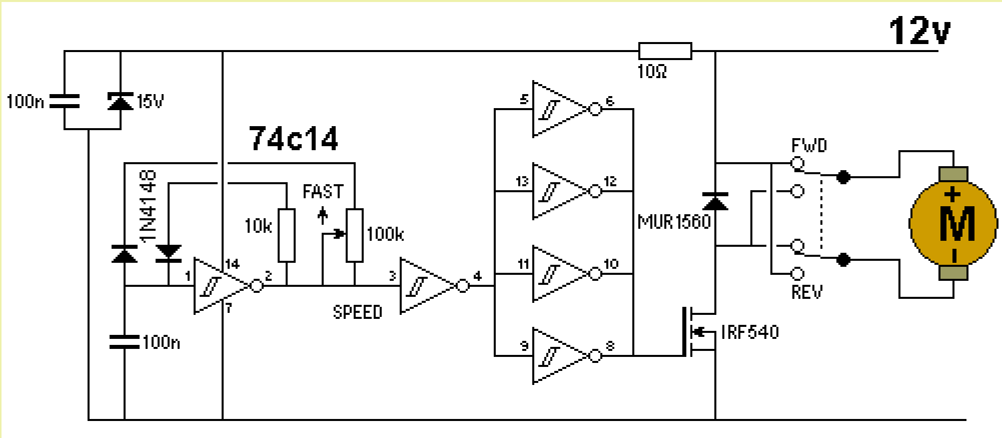


Input A HIGH, Input D HIGH - forward rotation
Input B HIGH, Input C HIGH - reverse rotation
Input A HIGH, Input B HIGH - not allowed
Input C HIGH, Input D HIGH - not allowed

The H-Bridge can be designed with two more transistors so that only two input lines are needed.

PWM MOTOR SPEED CONTROLLER

Here is a circuit from a 12v drill. The MOSFET will deliver up to 30Amps.
The frequency of the oscillator is in the range 550Hz to about 6.5kHz, with an off period of about 2.6us.



PWM 12v CORDLESS DRILL MOTOR CONTROLLER

WHY MOSFETs FAIL

There are quite a few possible causes for device failures, here are a few of the most important reasons:

- **Over-voltage:**

  MOSFETs have very little tolerance to over-voltage. Damage to devices may result even if the voltage rating is exceeded for as little as a few nanoseconds. MOSFET devices should be rated conservatively for the anticipated voltage levels and careful attention should be paid to suppressing any voltage spikes or ringing.

- **Prolonged current overload:**

  High average current causes considerable thermal dissipation in MOSFET devices even though the on-resistance is relatively low. If the current is very high and heatsinking is poor, the device can be destroyed by excessive temperature rise. MOSFET devices can be paralleled directly to share high load currents.

- **Transient current overload:**

  Massive current overload, even for short duration, can cause progressive damage to the device with little noticeable temperature rise prior to failure.

- **Shoot-through - cross conduction:**

  If the control signals to two opposing MOSFETs overlap, a situation can occur where both MOSFETs are switched on together. This effectively short-circuits the supply and is known as a shoot-through condition. If this occurs, the supply decoupling capacitor is discharged rapidly through both devices every time a switching transition occurs. This results in very short but incredibly intense current pulses through both switching devices.
  The chances of shoot-through occurring are minimised by allowing a dead time between switching transitions, during which neither MOSFET is turned on. This allows time for one device to turn off before the opposite device is turned on.

- **No free-wheel current path:**

  When switching current through any inductive load (such as a Tesla Coil) a back EMF is produced when the current is turned off. It is essential to provide a path for this current to free-wheel in the time when the switching device is not conducting the load current.
  This current is usually directed through a free-wheel diode connected anti-parallel with the switching device. When a MOSFET is employed as the switching device, the designer gets the free-wheel diode "for free" in the form of the MOSFETs intrinsic body diode. This solves one problem, but creates a whole new one...

- **Slow reverse recovery of MOSFET body diode:**

  A high Q resonant circuit such as a Tesla Coil is capable of storing considerable energy in its inductance and self capacitance. Under certain tuning conditions, this causes the current to "free-wheel" through the internal body diodes of the MOSFET device. This behaviour is not a problem in itself, but a problem arises due to the slow turn-off (or reverse recovery) of the internal body diode.

  MOSFET body diodes generally have a long reverse recovery time compared to the performance of the MOSFET itself.
  This problem is usually eased by the addition of a high speed (fast recovery) diode. This ensures that the MOSFET body diode is never driven into conduction. The free-wheel current is handled by the fast recovery diode which presents less of a "shoot-through" problem.

- **Excessive gate drive:**

  If the MOSFET gate is driven with too high a voltage, then the gate oxide insulation can be punctured rendering the device useless. Gate-source voltages in excess of +/- 15 volts are likely to cause damage to the gate insulation and lead to failure. Care should be taken to ensure that the gate drive signal is free from any narrow voltage spikes that could exceed the maximum allowable gate voltage.

- **Insufficient gate drive - incomplete turn on:**

  MOSFET devices are only capable of switching large amounts of power because they are designed to dissipate minimal power when they are turned on. It is the responsibility of the designer to ensure that the MOSFET device is turned hard on to minimise dissipation during conduction. If the device is not fully turned on then the device will have a high resistance during conduction and will dissipate considerable power as heat. A gate voltage of between 10 and 15 volts ensures full turn-on with most MOSFET devices.

- **Slow switching transitions:**

  Little energy is dissipated during the steady on and off states, but considerable energy is dissipated during the times of a transition. Therefore it is desirable to switch between states as quickly as possible to minimise power dissipation during switching. Since the MOSFET gate appears capacitive, it requires considerable current pulses in order to charge and discharge the gate in a few tens of nano-seconds. Peak gate currents can be as high as 1 amp.

- **Spurious oscillation:**

  MOSFETs are capable of switching large amounts of current in incredibly short times. Their inputs are also relatively high impedance, which can lead to stability problems. Under certain conditions high voltage MOSFET devices can oscillate at very high frequencies due to stray inductance and capacitance in the surrounding circuit. (Frequencies usually in the low MHz.)
  This behaviour is highly undesirable since it occurs due to linear operation, and represents a high dissipation condition.
  Spurious oscillation can be prevented by minimising stray inductance and capacitance around the MOSFETs. A low impedance gate-drive circuit should also be used to prevent stray signals from coupling to the gate of the device.

- **The "Miller" effect:**

  MOSFET devices have considerable "Miller capacitance" between their gate and drain terminals. In low voltage or slow switching applications this gate-drain capacitance is rarely a concern, however it can cause problems when high voltages are switched quickly.

  A potential problem occurs when the drain voltage of the bottom device rises very quickly due to turn on of the top MOSFET. This high rate of rise of voltage couples capacitively to the gate of the MOSFET via the Miller capacitance. This can cause the gate voltage of the MOSFET to rise resulting in turn on of this device as well ! A shoot-through condition exists and MOSFET failure is certain if not immediate.
  The Miller effect can be minimised by using a low impedance gate drive which clamps the gate voltage to 0 volts when in the off state. This reduces the effect of any spikes coupled from the drain. Further protection can be gained by applying a negative voltage to the gate during the off state. eg. applying -10 volts to the gate would require over 12 volts of noise in order to risk turning on a MOSFET that is meant to be turned off !

- **Conducted interference with controller:**

  Rapid switching of large currents can cause voltage dips and transient spikes on the power supply rails. If one or more supply rails are common to the power and control electronics, then interference can be conducted to the control circuitry.
  Good decoupling, and star-point earthing are techniques which should be employed to reduce the effects of conducted interference. The author has also found transformer coupling to drive the MOSFETs very effective at preventing electrical noise from being conducted back to the controller.

- **Static electricity damage:**

  Antistatic handling precautions should be used to prevent gate oxide damage when installing MOSFET or IGBT devices. But are very reliable once they are soldered in place.

For a mathematical approach to understanding the operation of a FET and some further circuits, here are four documents:

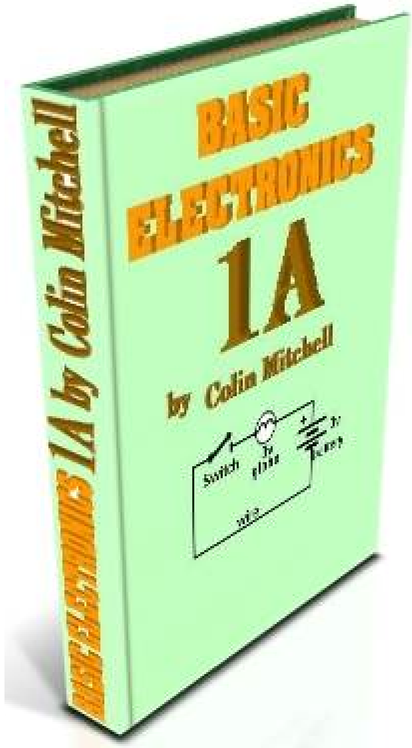
The FET .pdf 670KB
The FET Amplifier .pdf 310KB
MOSFET Basics .pdf 380KB
FET Principles and Circuits .pdf 1MB

This is just a start to learning about transistor circuits and more can be found on Talking Electronics website.
We have avoided mathematics and theory for a reason. Transistors have such wide parameters that theoretical values and "Computer models" do not work.
Most circuits have to be built and tested using transistors from different manufacturers to be sure they work every time. The author had a batch of transistors from a different manufacturer for his FM transmitters and THEY DID NOT WORK.
The gain at 100MHz was so poor, the FM Bug did not transmit.
The only way to learn is by "building circuits." Text books don't do this. Show me a text book that explains the output current for a common-emitter stage is dependent on the LOAD resistor (in the circuits above).
Show me a book that explains **why** capacitor-coupling two stages is so inefficient.
Or why the load resistor in Fig 25 should be 15 ohms and not 330 ohms.
You can get too tied up in mathematics and theory and as the saying goes: "You can't see the wood - (forest) - for the trees."
You have to be able to look at a circuit and see things "going up and down" or "passing energy from one stage to the next." And that's what we have tried to do.

24/8/2011 - constantly being updated and added-to

email Colin Mitchell for any extra theory you want added.

go to: Talking Electronics Website



For any enquiries email Colin Mitchell

INDUCTANCE

(and the INDUCTOR)

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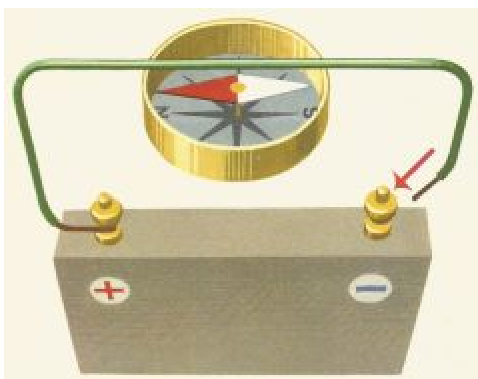
See our article on the INDUCTOR

INDUCTANCE is what an INDUCTOR has. It has INDUCTANCE. It has the ability to store energy in the form of magnetic flux and this energy can be stored in the CORE (the MAGNETIC CORE). Inductance is measured in **Henry** (H) , **milli-Henry** (mH) and **micro-Henry** (uH). An INDUCTOR is a coil of wire and it may be wound on a plastic former called a BOBBIN and the centre of the bobbin can be filled with a magnetic material called a CORE or MAGNETIC CIRCUIT. Inductance is a unit of storage, just like a battery has a storage of amp-hours.

INDUCTANCE

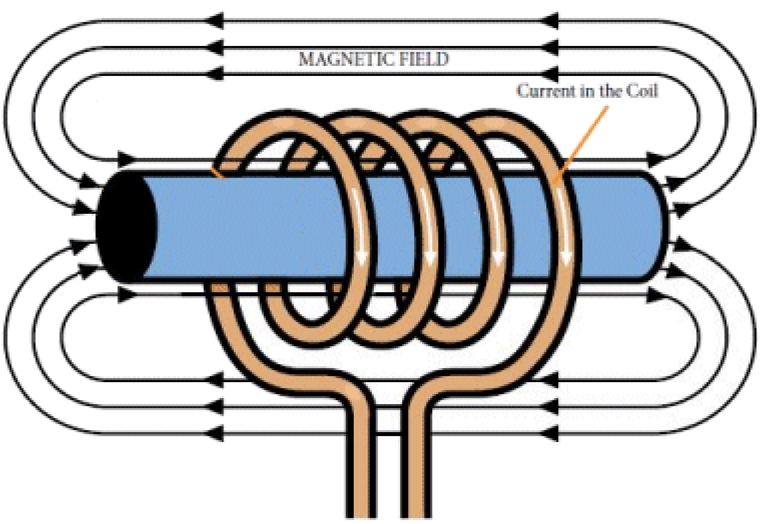
We are talking about how much energy can be stored by a coil of wire, called an INDUCTOR.
It has the units of: Henry (H) , milli-Henry (mH) and micro-Henry (uH).
But our discussion starts with a length of wire.
An amazing thing that happens when it is connected to a battery.
When a current flows through a piece of wire it produces magnetic flux.



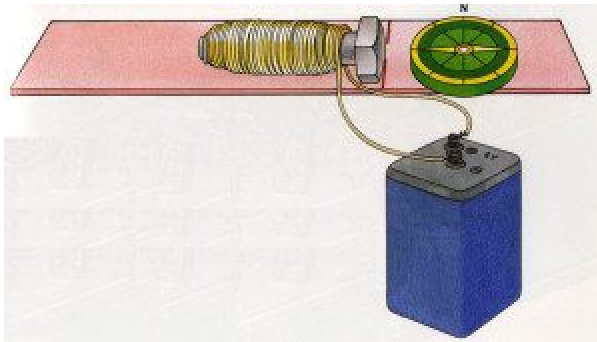
You can see this effect by placing a wire over a compass - the needle moves slightly.

To increase the movement of the needle, lots of turns of wire are wound on a cardboard tube (called a former).

By increasing the number of turns, the needle will rotate more.
Don't worry about which way it rotates or how much it rotates, the needle shows magnetic flux is being produced by the coil.

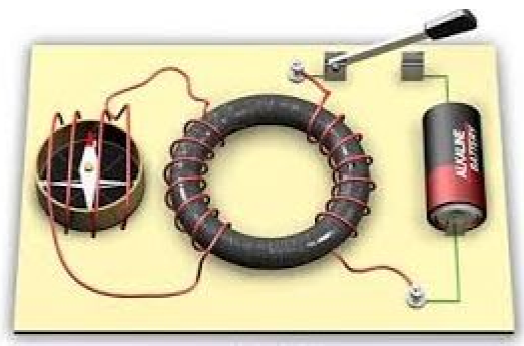


This is how we draw the magnetic lines produced by the current in the coil. The lines emerge from one end of the rod, pass around the outside and enter the other end. These lines make it easy to describe what is occurring.

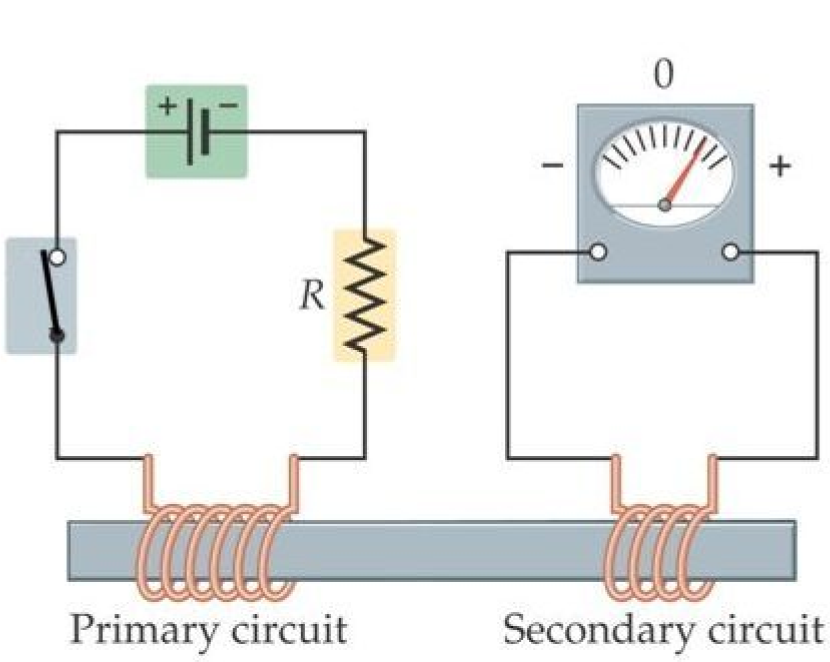


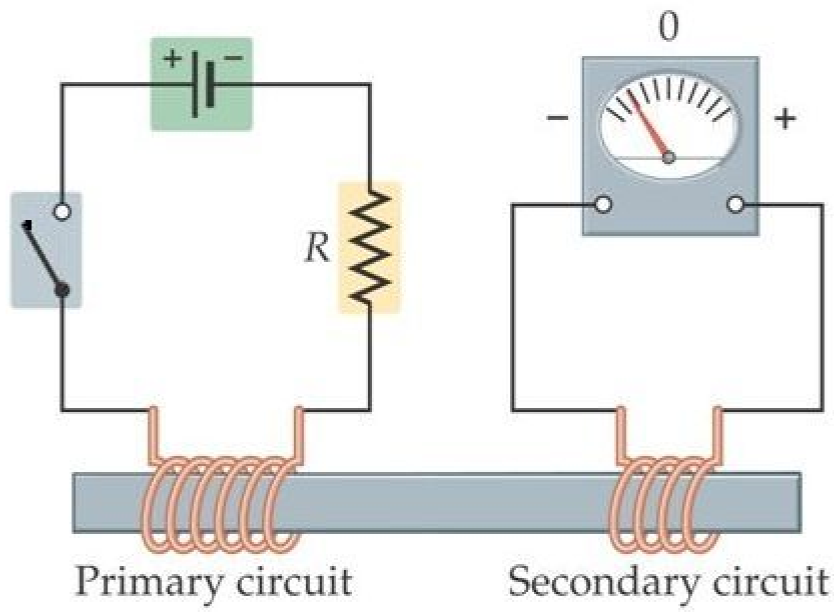
By winding the coil on a nail, screw or bolt, the magnetic flux from each turn is added together (called concentrated) and comes out the end of the bolt.
These experiments were demonstrated over 100 years ago and everyone thought they were amazing.
It was the first time electricity had an effect on moving an object.

Now we come to something that is more amazing.
When the switch is closed (called a knife switch), the compass needle moves slightly clockwise and then returns to "North."
When the switch is opened, the needle moves anti-clockwise and returns to "North." The "up-down" position of the needle is simply to set it so it can move clockwise and anticlockwise.

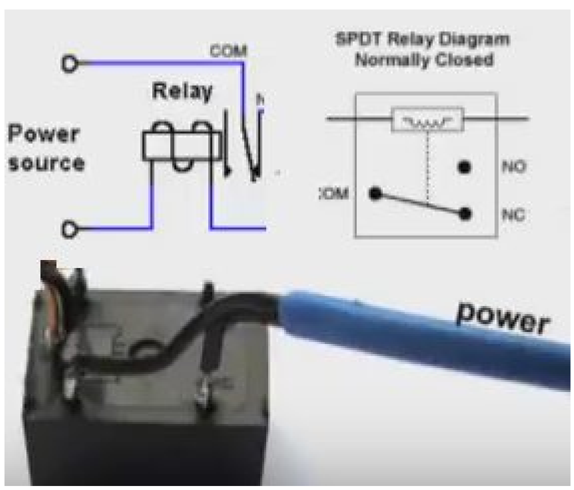


When this was demonstrated over 100 years ago, there was no other test equipment and the demonstrator Michael Faraday concluded that voltage was induced in the compass coil - in one direction - when the switch was closed and induced in the other direction when the switch was opened. The two coils did not touch each other and the only thing connecting them was magnetic flux through the ring. (the ring is called a ferrite ring or fine powered iron ring.)
This is also shown in the following two diagrams:





Here's the next amazing feature.
When you turn off a circuit containing a coil, a very high voltage appears across the ends of the coil.
You can feel this by connecting 12v to a relay and hold the wires in your two hands. When you remove the wires, you will feel a zap.
You can also connect the relay as shown in the diagram below so is buzzes when the voltage is applied. Feel the terminals by pressing firmly with your fingers and you will get a zap.



This means the 12v is converted to at least 80v to give you a zap.
How does this happen???
The relay contains a coil of thousands of turns.
When you connect the supply, the coil produces magnetic flux (commonly called magnetism).
When you remove the supply, the magnetic flux collapses and cuts all the turns of the coil and produces a very high voltage IN THE OPPOSITE DIRECTION.

This means a coil has 2 uses. It can deflect a compass needle or pick up nails or scrap metal to load into a ship etc or it can be used for its ability to produce a high voltage.
The first is called its DC use - as an electromagnet and the second is its AC use as an INDUCTOR.

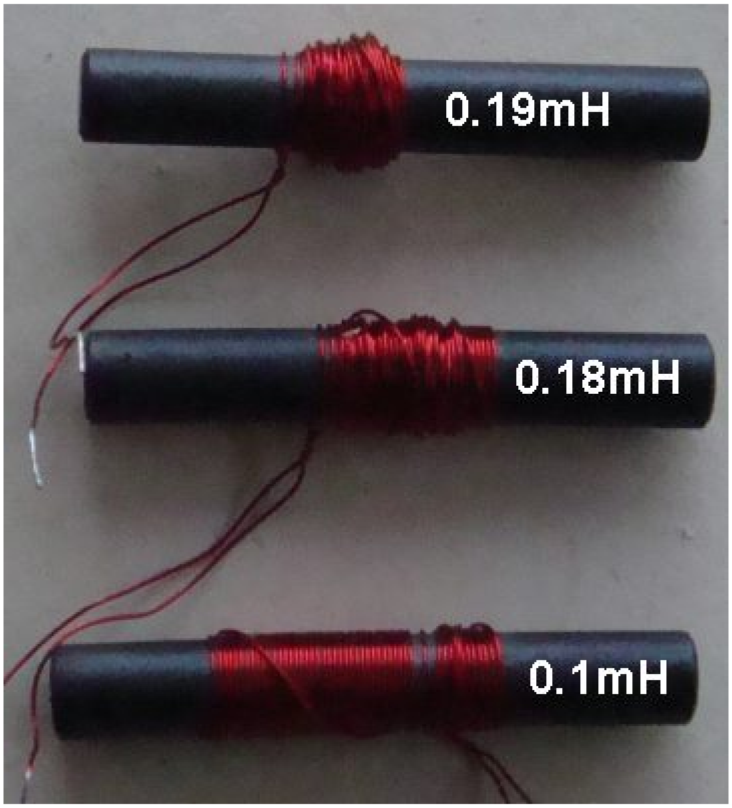
We will be discussing its AC use (its use in AC circuits). AC circuits are circuits with a signal - a frequency.
We are not going to produce a high voltage but we are interested in the fact that a voltage is generated IN THE OPPOSITE DIRECTION to the supply voltage.
This "zap" voltage is only generated (produced) when the supply is turned OFF or if the voltage

reduces quickly.
If the voltage reduces quickly, this voltage is very high.
The voltage has a name: It is called **BACK EMF**. (It can also be called **FLYBACK VOLTAGE**).
Let us go even further.
When an increasing voltage is delivered to the coil, the magnetic flux produced by each of the turns, cuts each of the other turns and produces a voltage in the opposite direction.
That's right. You can imagine the complexity.
Each turn is producing magnetic flux and this flux passes each of the other turns and produces a very small voltage in each turn that is opposite to the supply.
This is the end result: The supply might be 12v and the back voltage can be as high as 11.9v
This means the effective forward voltage is only 0.1v and by using Ohm's Law, the current flowing through the coil will be very small.
This effect only occurs when the voltage is rising and falling.
When the current is steady, the coil is simply an electromagnet, such as a magnet to pick up pins or nails and we are not concerned about this state.
When the voltage is rising, the current is increasing and the flux is increasing. This is called EXPANDING FLUX.
When the voltage is decreasing, the current is decreasing and the flux is called COLLAPSING FLUX.
This means there is a voltage and current opposing a voltage being delivered to a coil and this reduces the current flowing into the coil.
Thus a coil behaves completely differently when a rising and falling voltage is delivered to it.
And that is what we are going to cover.
When an AC voltage is applied to a coil, the turns produce a back voltage that reduces the current entering the coil. This effect is like "pushing against" the current trying to enter the coil and technically we say the current is IMPEDED - PREVENTED - REDUCED.
In other words, the coil has IMPEDANCE.
Impedance has the units of OHMS but it is not obtained via an Ohmmeter.
Impedance is a calculated value and we will give a simple example:
Suppose a coil takes 3 amps when connected to a 12v supply. This is the case of the coil being an electromagnet and the resistance is 4 ohms.
But when an AC signal is applied, the average current is just 1 amp. (This is because the coil is creating a back voltage and because the resulting forward voltage is very small, only a small current flows).
by using Ohm's Law, the answer is 12. We cannot say the resistance is 12 ohms because we have already said it is 4 ohms. Thus we have to give another name to the number "12."
And we say the impedance is 12 ohms.
If we increase the frequency, the current may reduce to 0.5 amps.
In this case the impedance is worked out to be 24 ohms.
Thus the impedance will change according to the frequency of the voltage being applied to the coil.
Now we come to the word INDUCTANCE.
Inductance is given the units HENRIES. (H) and the sub-multiples milli-Henries (mH) and micro-Henries (uH)
The value of Henries does not change with frequency or current or voltage. It is a fixed value.
To measure the inductance of a coil is VERY COMPLEX and beyond our discussion.
You will never need to determine the inductance of a coil from "first principles" (complex mathematics and complex test equipment) but a simple way is to place it in a circuit that is oscillating with a known inductor, then replace it with an unknown inductor, then use known values until you get the two frequencies to be the same.

Don't get names and values confused.
We talk about **CAPACITIVE REACTANCE** and **INDUCTIVE IMPEDANCE.**
Not: CAPACITIVE IMPEDANCE or **INDUCTIVE REACTANCE.**
Although REACTANCE and IMPEDANCE are very similar features, try to keep the word REACTANCE for a capacitor and IMPEDANCE for an inductor.
Reactance is mathematically symbolized by the letter “X” and is measured in the unit of ohms (Ω). And is used for capacitors.
Impedance is mathematically symbolized by the letter “Z” and is measured in the unit of ohms (Ω), in complex form. And is used for Inductors.
Any further discussion along these lines involves (complex) mathematics.

Here are 3 inductors. They are all 50 turns on 6mm x 40mm ferrite rod. A ferrite rod is simply an iron rod made with very fine particles of iron, pressed into a rod.
The winding is bunched-up on the top inductor, slightly spread on the middle and one layer on

the lower inductor.
BUT the inductance is much less for the single winding.
That's why it is very difficult to determine the value of inductance for a winding without taking a measurement. The length of the rod (20mm) reduces the middle inductance to 0.14mH.



50 turns on 6mm x 40mm

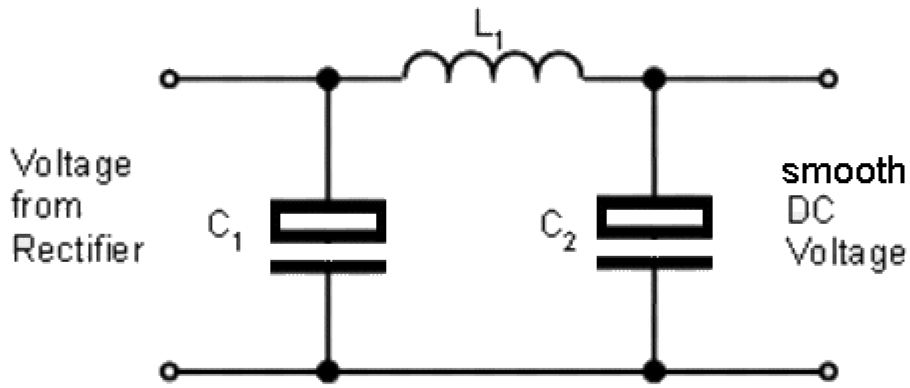
50 turns on 10mm x 40mm

Comparing the 0.19mH rod above with the 0.2mH rod, you can see the diameter of the rod made very little difference to the value of inductance. The properties (quality) of the magnetic material in the rod may have influenced the result.

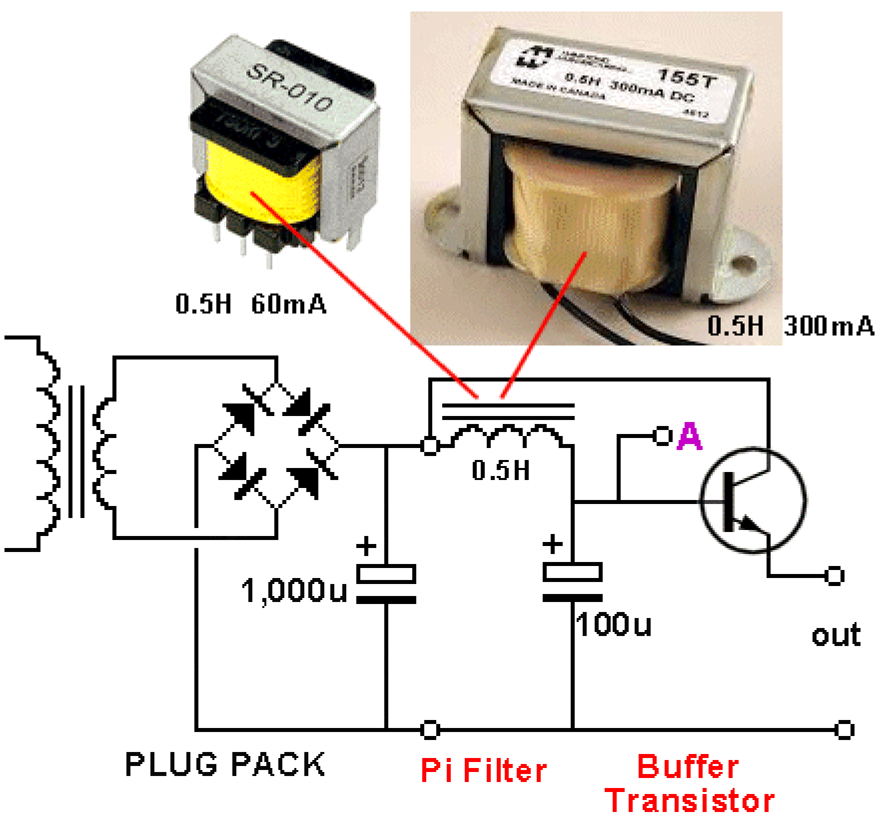
An inductor has over 20 different uses. We are going to look at some circuits using an inductor.

The "Pi" FILTER

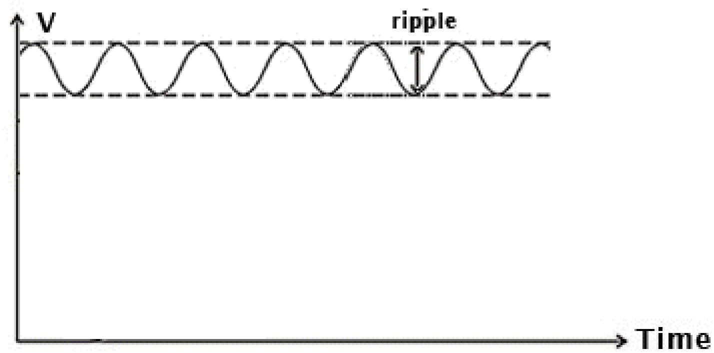
A Pi Filter consists of a capacitor, an inductor (or a resistor) and finally another capacitor. Each of the three components in this circuit reduces the ripple. The amount of reduction depends on the value of each component.



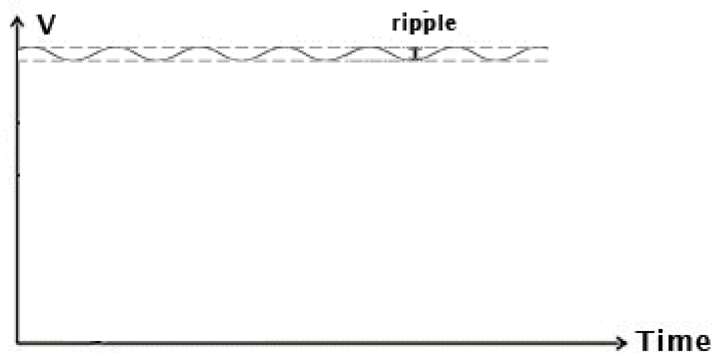
A Pi Filter consists of: capacitor - inductor - capacitor
It can also use: capacitor - resistor- capacitor but a larger voltage-drop will appear across the resistor.



The two capacitors (electrolytics): To understand how a capacitor works, you will have to look on the internet "WALKING ON CUSTARD."
If you have a swimming pool filled with custard, you can run over the surface and not fall in because the custard resists being "hammered" by your feet. But if you slow down, you will fall in. That's how a capacitor works. When a voltage is connected to a capacitor, it charges. If the voltage rises and falls a small amount, the capacitor charges and discharges and it takes time to charge and discharge. This slows down the time the voltage can rise to its original value and it only gets to charge a small amount before the voltage starts to fall again. That's why the voltage rises and falls LESS than before. This covers both capacitors.
Now we come to the inductor.
We know an inductor allows a steady voltage to pass through without any change.
The voltage being filtered by this circuit consists of a steady voltage with an AC component.



Ripple before Pi Filter

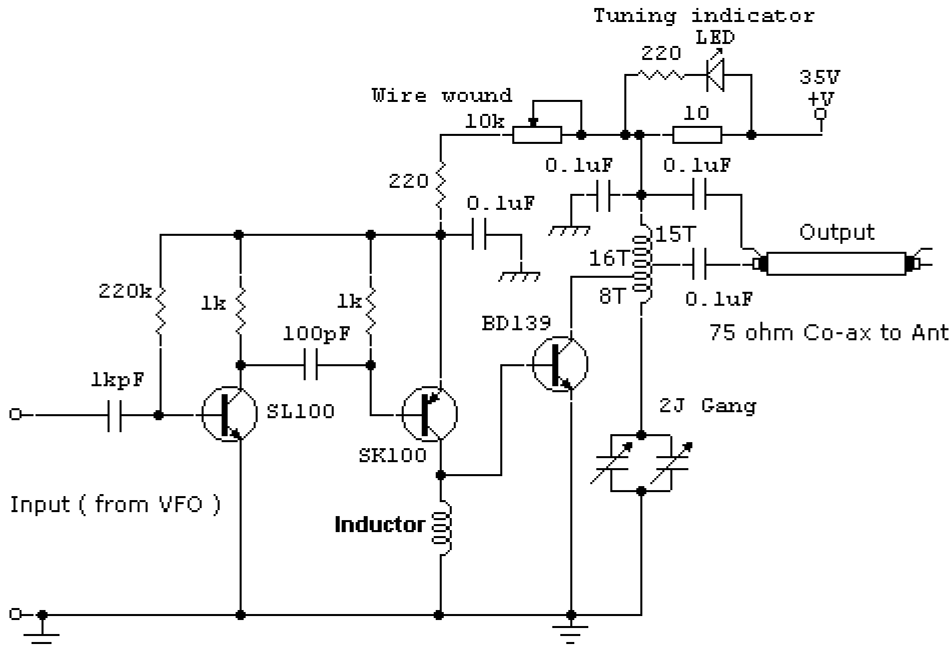


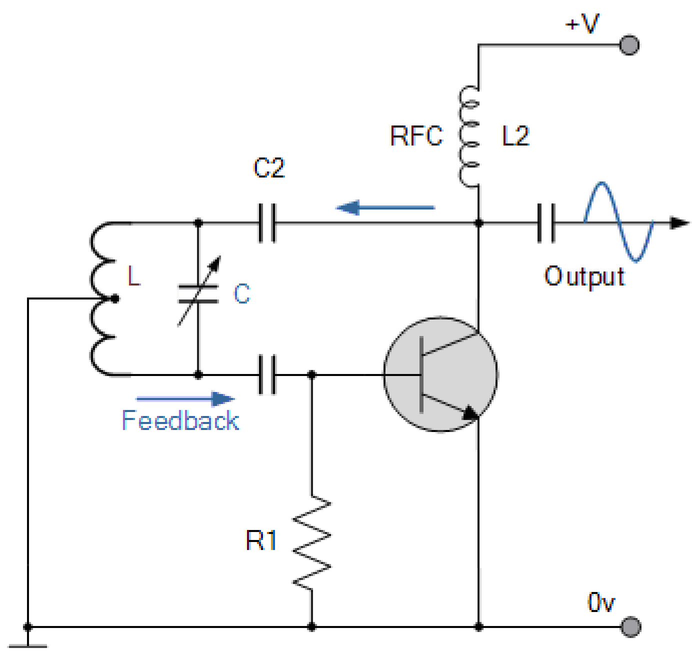
Ripple after Pi Filter

The diagram (graph) shows a voltage with a ripple. The height of the "squiggle" is the amplitude of the ripple. The arrows show the amplitude of the ripple. This ripple is shown on the graph at a height from the "time" line. The time line is also the 0v line and the distance between this line and the ripple is the approximate DC component of the voltage.
The ripple after the Pi Filter will be very small as shown in the second graph.

The steady voltage is called the DC component and this is not altered by any of the three components in this filter.
It is the ripple (the AC component) that produces the expanding and collapsing magnetic flux and when this ripple enters the inductor it produces magnetic flux and this flux cuts all the other turns to produce a voltage in the opposite direction.
This magnetic flux absorbs some of the energy contained in the voltage and this reduces the height of the peak.
This reduces the peak portion of the ripple.
When the ripple drops to a lower value, a point is reached where it cannot produce any flux and the flux stored in the core of the inductor starts to collapse and produces a voltage in the turns that increases the voltage flowing through the inductor and thus the emerging voltage is slightly higher than the original lowest value.
This increases the trough portion of the ripple.
In other words it "smoothes out" the peaks (highest points) and troughs (lowest points) by taking some of the voltage from the peak and adding it to the lowest value via the energy in the magnetic flux.
This type of filter is very effective in reducing ripple, but it is large compared to other forms of filters and the inductors are expensive.

The INDUCTOR AS A SEPARATOR



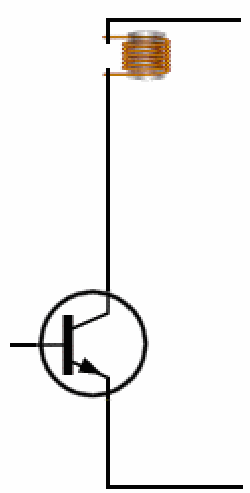


Finally we have the inductor as a SEPARATOR.
When an inductor is used in a circuit as shown above, it is commonly called a CHOKE. This is really to emphasize the fact that the signal does not pass through the inductor - in this circuit.
It allows DC to pass (called the current in the circuit) but prevents AC (called the signal in the circuit).
The inductor has a very small resistance and it allows current to flow through it so the transistor stage works very successfully.
The transistor is amplifying a signal and the signal emerges from the collector in the first circuit and the emitter in the second circuit.
If the inductor was a resistor of very small resistance, the transistor would have to be turned on via large amount of base current to achieve the bottom part of the waveform.
If the resistor is a large value, the transistor will not get sufficient base current to produce a waveform. This is because the collector voltage will drop very quickly and rob the base from getting a voltage and current - the transistor will not get turned ON and only the top of the waveform will be produced.
However the inductor has a very small resistance and it allows current to flow through it so the transistor stage works very successfully.
Here's how it works:
Normally, when the transistor turns ON, and the load is a resistor, the resistance across the

collector-emitter terminals decreases and the current increases.
The increasing current through the load resistor produces a high voltage-drop and this is how the lower part of the waveform is generated.
When the load-resistor is replaced by an inductor, the transistor turns on more and a higher current flows through the inductor.
This produces more magnetic flux and a higher voltage is produced by the inductor and this voltage lowers the voltage on the collector.
In other words, a voltage is produced across the inductor, just like a voltage is produced across a load resistor.
In both cases VOLTAGES are produced due to the current flowing, but the inductor produces the voltage due to magnetic flux and the resistor produces voltage due to Ohms Law.

What is the advantage of the inductor?
It takes less "effort" for the transistor to turn ON fully.
The inductor finds it very easy to produce a voltage that "pushes" the collector away from the positive rail and this is how the waveform is produced. It may even be responsible for producing a larger waveform - depending on the circuit.
The inductor also has a "smoothness" about how it delivers the voltage and this helps to produce a clean waveform.
In some circuits it improves the performance enormously.

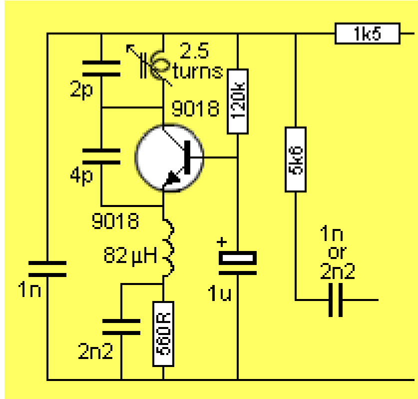
Here is an animation of an inductor and transistor.



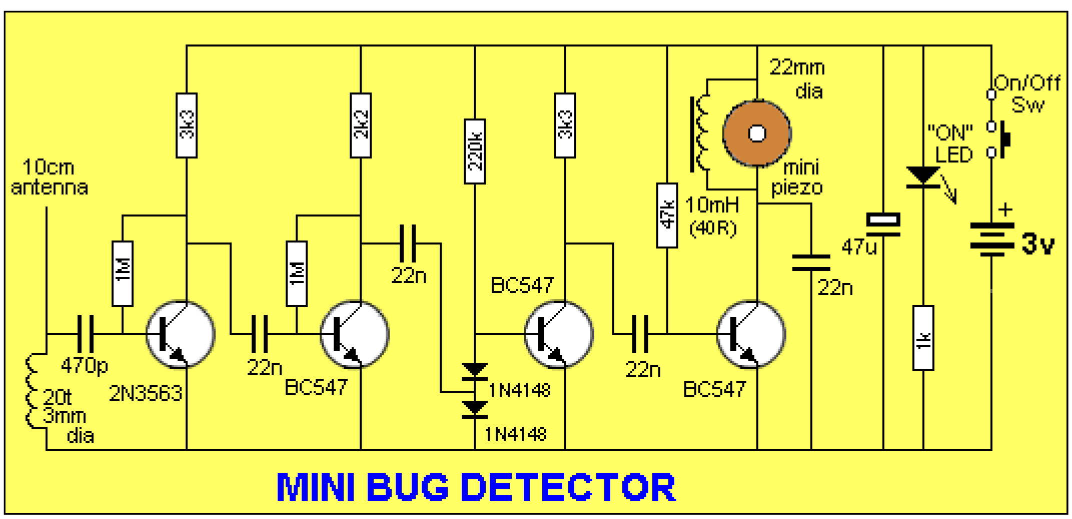
The transistor is turned ON more and more via the base.
This makes more current flow through the collector-emitter terminals and we have shown this by the transistor getting smaller and smaller.
This causes more current to flow through the inductor and the increased current makes more flux.
The additional flux cuts all the turns of the coil and creates a voltage in each turn that is opposite to the applied voltage and a negative voltage appears on the lower lead of the inductor.
This puts a lower voltage on the collector and it is easier for the transistor to turn ON harder.
Increasing the current into the base does not turn the transistor ON an equal amount because the gain of the transistor reduces as it gets turned ON more and more.
This causes the inductor to produce a varying output voltage and the result is a waveform that is curved, similar to a sinewave.
The main point to understand is this:
The inductor makes it easier for the transistor to produce a waveform and it improves the shape of the waveform.

2 CIRCUITS

Here are 2 circuits using the features of an inductor we have mentioned above.
Here's the feature:
When an alternating signal is presented to one of the terminals of an inductor, it produces a voltage equal to the incoming voltage.



The signal we are talking about comes from the collector and into the emitter via the 4p.
The inductor allows the signal from the collector to pass to the top of the inductor via the 4p capacitor and then into the emitter of the transistor.
The inductor allows the signal to rise and fall very easily and this makes the voltage on the emitter rise and fall.
It is not easy making the emitter rise and fall and that is another topic for discussion.
The base is firmly fixed via the 1u and when the emitter rises and falls, the collector-emitter current rises and falls and this produces the waveform in the 2.5 turn coil.
The bottom of the inductor is held firm via the 2n2 and the 560R is a current-limiting resistor to only allow a small current to flow in the circuit. If too much current flows, the transistor gets swamped and overheats.
The inductor does two things. It allows the signal to pass from the 4p to the emitter and it has a very low resistance so that only a very small DC voltage appears across it. We have already created a large voltage across the 560R and we don't have any more voltage available, otherwise the voltage for the transistor will be so small that the output waveform from the transistor will be very small. The inclusion of the inductor and the 2n2 allows the transistor to produce a large output. It is really only a few millivolts but it is amplifying the microvolts from the air.
The inductor can be replaced with a resistor and two things will happen.
Some of the signal from the 4p will be lost in the resistor and a voltage will appear across the resistor and this will reduce the output amplitude of the stage.
The value of the inductor is quite critical and it consists of about 70 turns.
It improves the sensitivity of the circuit about 25%. A 60 turn or 80 turn coil will give very poor results - it must be 70 turns for this particular circuit. The actual number of turns depends on the frequency and can only really be determined by experimentation.



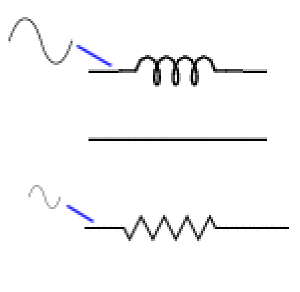
This circuit uses an inductor at the front-end to improve the sensitivity.
It looks like the coil is a short-circuit to the signal, but it forms a very simple parallel circuit with the 470p that collects all the signals and uses the energy to produce some signals with a higher amplitude. This makes the circuit much more sensitive.

MANY TYPES OF INDUCTORS

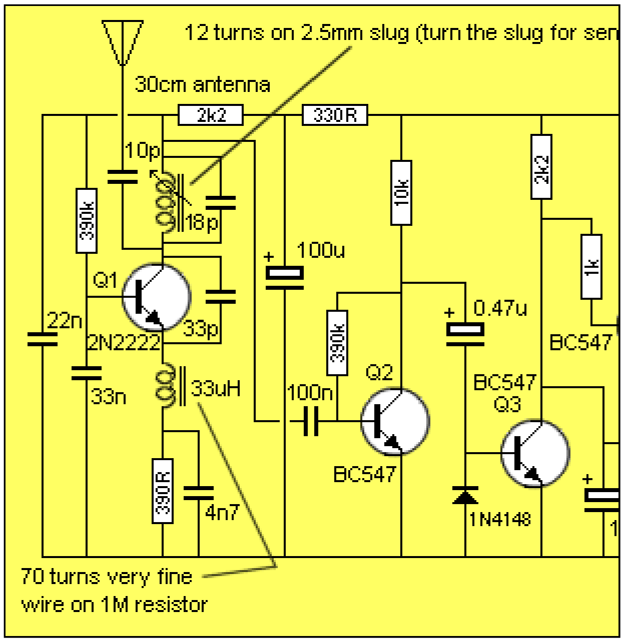
There are thousands of different inductors on the market and many more that have been made especially for a particular application.
You cannot look at an inductor and work out its features.
Here's why:
An inductor has a value called its inductance and this is usually marked via colour bands or written on the component. You can measure this value in an INDUCTANCE METER. The meter sends a pulse through the coil and measures result. But this is not a "real circuit" evaluation. The inductor may react differently in an actual circuit.
And there is another "hidden" value and this is its ability to work at high frequencies. This feature depends on the type of material used in the core. Air cores work to the highest frequency.
The "Quality Factor of air is "1." Some materials have a "Quality Factor of 100 or more and this means the coil is one hundred times better than and air cored inductor.
Basically the Quality Factor means the inductor will produce a back voltage 100 times greater than the supply voltage during a particular test.
As the frequency of testing increases, the back voltage decreases and at some point the voltage is the same as the input voltage. This becomes the F_T of the material and it is no better than an air inductor.
The Quality Factor is often shortened to "Q."
Another factor that you have to be aware of is CURRENT CAPABILITY.
One inductor can be wound with fine wire and have a high resistance. Another inductor can be wound with thicker wire and have the same inductance.
But the second inductor will not work in the same circuit because the circuit is sensitive to the value of resistance.
In addition, inductors can have different "Q" values. Some inductors are called "High-Q" inductors and these are suitable for connecting across a capacitor to make a circuit called a RESONANT CIRCUIT that produces a high voltage at a particular frequency. It can also be called a TANK CIRCUIT when used in Radio Frequency circuits.

HOW THE INDUCTOR WORKS

Here is a very simple way of explaining how the INDUCTOR works. An INDUCTOR is simply a coil of wire on a cardboard tube or wound on a metal core.
It is an electrical component but suppose we explain it as a mechanical item.
Suppose we connect one end to a wall and turn it into a lever. If we lift the lever, the lever reacts by lifting itself at the same time. This makes it very easy to lift the lever.
This is how an inductor reacts to a rising voltage. If one end of the inductor is tied to the wall, the voltage on the other end rises at the same rate as the voltage you are applying. This makes it very easy for the incoming voltage to rise.
If we replace the inductor with a resistor, it is like using a lever made out of a thick piece of rubber. To raise the lever we need to stretch the rubber and this is hard to do. The rubber does not assist the incoming voltage and tends to work against it.



Basically, a waveform trying to enter an inductor will have a higher amplitude than the same waveform trying to enter a resistor. The inductor will be producing a back-voltage that will help the waveform because it will not allow as much current to enter the inductor and this will not reduce the amplitude as much as the resistor shown in the second diagram.

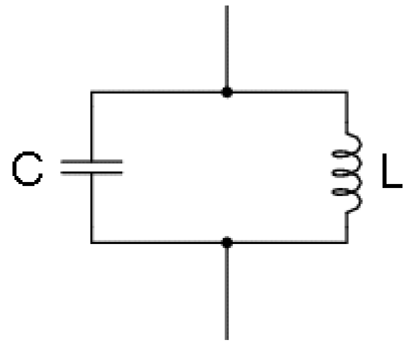


27MHz receiver

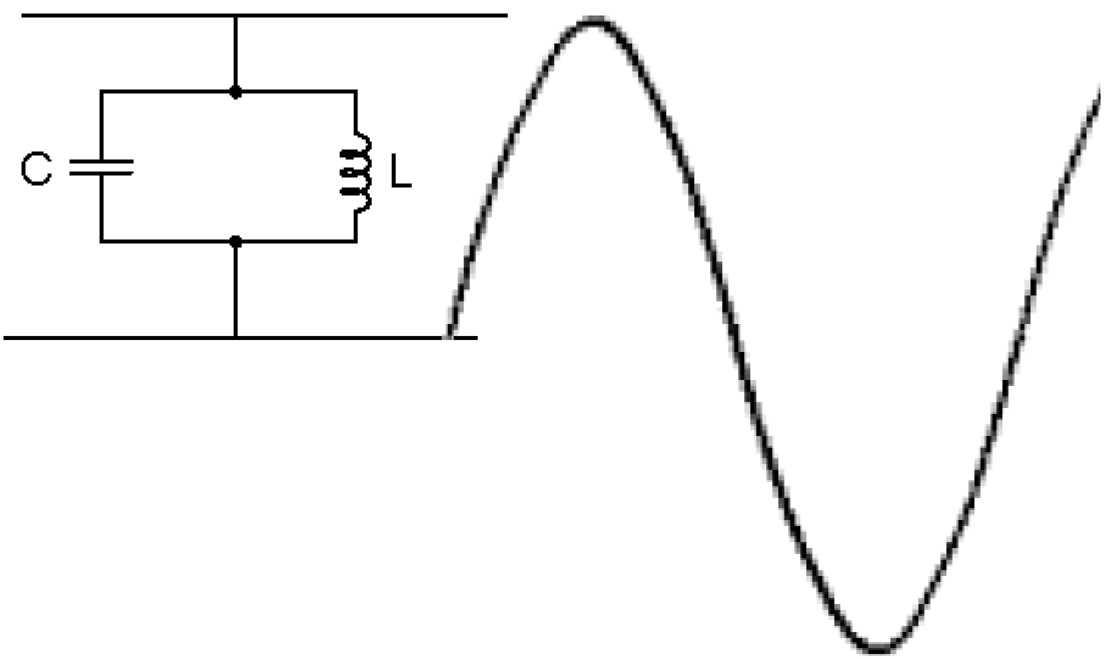
Now that we have explained how an inductor works, we can explain the 33uH in the circuit above.
The circuit operates at 27MHz and the first transistor is actually oscillating all the time, even though the circuit is a receiver.
This is the clever part of how this type of circuit works.
The fist transistor is oscillating at a very low level and it is sending out a signal on the receiving antenna.
When it picks up a signal with exactly the same frequency, the two signals interfere with each other and the transistor takes more current and less current at a much lower frequency called the audio frequency.
This clever idea has been introduced because it is much easier to control an oscillator that is already oscillating that try to start up an oscillator circuit.
Now we come to the purpose of the 33uH.
The first thing to remember is this: A capacitor has a very big effect on blocking or passing a frequency that is a HIGH FREQUENCY. It will either block or pass the frequency, depending on where the capacitor is located in the circuit.
And the same thing applies to an INDUCTOR. Its effectiveness will be very high when the frequency s very HIGH.
That's why the value of a capacitor or inductor can be quite small. Even a low value will have a noticeable effect.
In the circuit above, the 4n7 will have an effective resistance of less than 2 ohms at 27MHz, so the bottom lead of the 33uH will be effectively connected to the 0v rail, as far as the transistor is concerned.
Now we come to the transistor. There are two ways to turn ON a transistor. One is to keep the emitter fixed and increase the voltage on the base and the other is to keep the base fixed and reduce the voltage on the emitter.
We have kept the base fixed. The 33n on the base prevents the base moving.
This means, to turn ON the transistor, we must reduce the voltage on the emitter.
As mentioned above, the transistor is oscillating all the time at 27MHz. This frequency is determined by the top 12 turn coil and the 18p capacitor. These two components form a parallel tuned circuit and the transistor is initially turned on by the biasing components and the 390k on the base.
The tuned circuit creates a sinewave and during the production of the complete cycle of the sinewave the transistor is turned on and off.
The tuned circuit does this by delivering a pulse to the base via the 33p capacitor and when a negative pulse is delivered to the emitter via the capacitor, the transistor is turned ON more.
When a positive pulse is delivered, the transistor is turned OFF more.
But what we want to emphasize in this discussion is the action of the 33uH inductor. When the pulse is delivered by the 33p, the inductor "meets" this pulse (amplitude) and produces a voltage of equal amplitude and this has the effect of not reducing the amplitude. This means the full amplitude can be applied to the emitter where it has the greatest effect on either increasing or

reducing the voltage.
If the inductor is replaced with a resistor, some of the energy from the pulse will be absorbed by the resistor and the sensitivity of the circuit will be reduced.
In fact, the impedance of the inductor is so critical that a few turns more or less will reduce the performance by 10% or more.

THE RESONANT CIRCUIT - also called the TANK CIRCUIT



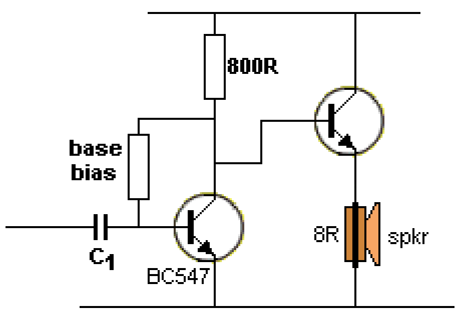
The Capacitor is classified as a PASSIVE COMPONENT because it does not amplify.
The Inductor is classified as a PASSIVE COMPONENT because it does not amplify.
But when these two components are connected across each other, an amazing thing happens.
This amazing thing was detected in the early days when scientists were demonstrating coils and capacitors and creating sparks with batteries and wires.
When the coil and capacitor were placed in parallel, the sparks increased in size and after further experimenting the scientist found the circuit worked best at a particular frequency.
This was years before radio and the scientists though the circuit stored energy and released it at a particular frequency.
When radio transmission came along, this circuit was used to increase the output on a particular frequency and the name TANK CIRCUIT was given to the combination.



The diagram above shows a TANK CIRCUIT - A RESONANT CIRCUIT that oscillates at a particular frequency, determined by the value of C and L.
Not only does it oscillate and produce a beautiful sinewave output, but the wave is TWICE the voltage of the supply.
To see how it works, we very briefly connect a voltage.
The capacitor charges to full rail voltage and the inductor sees this voltage and produces a back voltage that opposes the voltage and it produces very little magnetic flux.

The supply is now removed.
The capacitor now delivers its energy to the inductor and the inductor produces a back voltage. If the energy tries to be delivered too fast, the back voltage increases and slows down the process.
This is how the shape of the waveform is produced.
A point is reached where the energy from the capacitor is not enough to maintain the flux in the inductor and it starts to collapse and produce a voltage in the opposite direction.
This charges the capacitor IN THE OPPOSITE DIRECTION and that's how the waveform below the bottom rail is generated.
This action will occur a few more times, but each time the amplitude of the sinewave gets smaller.
When these two components are connected to a circuit, they send out a signal so they are injected with a small amount of energy to maintain the exact same frequency of operation.
That's why this circuit is called a TUNED CIRCUIT, because it is TUNED or SET or ADJUSTED to operate at a particular frequency. It is these two components that set the frequency. The transistor driving the two components simply injects a small amount of energy at the appropriate time to keep them OSCILLATING.
The end result is the waveform is TWICE the voltage of the supply. In other words, the circuit has amplified the voltage of the supply.
This is what they have done:
They have turned pulses of energy from a transistor into a very smooth sinewave.
They have "controlled" the transistor and set the frequency of operation.
They have produced a sinewave that is double the voltage of the supply.

8R SPEAKER Vs 50R SPEAKER



A speaker is an inductor.
Most of the speakers used in transistor radios have an impedance (resistance) of 8R for the VOICE COIL. This has been chosen because it is very easy and cheap to produce. The wire in the coil is also quite thick and robust.
But it is interesting to note that speakers with a high resistance voice coil will produce an equal volume and require less driving current. This applies to 33R speakers as well as 50R speakers.
The reason is this:
Moving the cone requires a certain amount of flux and this can be produced by a small number of turns and a high current or a large number of turns and a low current.
The flux is a product of turns x current and this is called AMP-TURNS. In other words, AMPS x TURNS (number of turns in the coil of wire).
A speaker is a LINEAR ACTUATOR and the principle of AMP-TURNS can be applied when designing one of these devices.
Other, closely related devices include the ELECTROMAGNET - for picking up scrap steel, DOOR RELEASE - for unlocking a door, LINEAR MOTOR - for high speed trains and levitation, and the electric motor - such as the 3-pole motor.
And there are dozens of other devices that use a coil of wire that has INDUCTANCE, for an application that uses the magnetic flux produced.
Sometimes the inductance comes into the calculation because it limits the frequency at which the device will operate.
This topic can become very complicated.
The simplest of all electrical devices - a coil of wire - has the largest number of applications in electrical circuits and electronic circuits - and requires some of the most complex theory to understand.

HIGH-VOLTAGE - FLYBACK

All the circuits above are "controlled." By this we mean the waveform is rising and falling at a known rate.
In these conditions, the output from the inductor will be slightly less than than the incoming voltage.
If the voltage was the same, there would be no resulting input voltage and no current would flow and no flux would be produced.
But **if** the incoming voltage is turned off instantly, the magnetic flux collapses very quickly and the voltage produced by the inductor can be 10 times to 1,000 times greater than the supply.
This is called a **FLYBACK VOLTAGE** and there is a whole range of circuits using this feature.
That's why you have to "see" a circuit working to be able to work out what is happening.

RECAPPING

A coil of wire on a former is called a **SOLENOID** or **ELECTROMAGNET** or **INDUCTOR**. It can also be called a **CHOKE**.
When there are two separate windings it is called a **TRANSFORMER**. (or the two winding can be joined in the middle and it is still called a transformer - an **AUTO TRANSFORMER**).
A **FORMER** is a cardboard or plastic tube and it can be AIR CORED - nothing in the middle.
A metal rod in the middle is called a **CORE**. It can be a nail, brass screw, iron rod, ferrite rod, ferrite core, steel, or thin sheets called **LAMINATIONS**.
All these materials have a different effect and different result on the inductance of the coil and some of the results will surprise you.
When a voltage is applied to an inductor, current starts to flow and this produces magnetic flux that cuts all the turns of the coil to produce a BACK VOLTAGE called BACK EMF.
This "pushes against" the incoming voltage and the result is only a small incoming voltage is available. This small voltage only allows a small current to flow and that's why it takes a long time (microseconds) to get the full current to flow.
When the full current flows, the back voltage is not produced but the inductor is producing the maximum magnet flux.
When the supply is turned OFF, this magnetic flux collapses and cuts all the turns of the coil and because there is nothing opposing this voltage, and the resulting voltage is ENORMOUS.
It can be 10 times to 1,000 times larger than the supply and this is the "zap" you get when you hold the ends of the coil in your fingers.
This voltage has a polarity that is OPPOSITE to the voltage of the supply.
The **INDUCTANCE** of a coil is measured in Henries, milli-Henries or micro-Henries.
The colour bands on an inductor are in microHenries.
The numbers on a surface mount inductor are micro-Henries.
The numbers on other inductors are micro-Henries.
Such as 104 = 100,000 micro-henries = 10 milli-Henries. See **our other article on the INDUCTOR.**

Here is a colour code calculator from the web:
http://www.electronics2000.co.uk/calc/inductor-code-calculator.php

Here is a colour code calculator for Resistors, Inductors and other things:

MAKING YOUR OWN INDUCTOR

Making an inductor is very complex and using a formula will only cause frustration.
Here is the only way to design your own inductor:

Go to eBay (and also try electronic parts suppliers) and buy a whole range of inductors and test them in the circuit you are designing.
The material of the core as well as the current capability of the inductor is also important - so the size of the wire may be one of the things you have to consider.
If it works perfectly, use it. Make sure it does not get hot.
If you want to change the inductance slightly, you can remove the heatshrink and remove some of the turns.
If you want to know the value of inductance, buy an inductance tester from eBay for $15.00.
It tests resistors, capacitors, inductors and electrolytics.
You can increase the inductance by adding turns, but it is much easier to remove turns from a larger inductance.
Only remove a few turns at a time.
When you have finished you can count the turns but you must get the same core to achieve the same inductance.

SELF INDUCTANCE AND MUTUAL INDUCTANCE

These two terns sound complex but they simply mean:
SELF INDUCTANCE refers to the inductance of a single coil with a single winding.
MUTUAL INDUCTANCE refers to an inductor with 2 windings (or 3 or more) where one winding is being supplied with a waveform and the magnetic flux is passing to the other winding and producing a waveform. An example is a transformer.

to Index

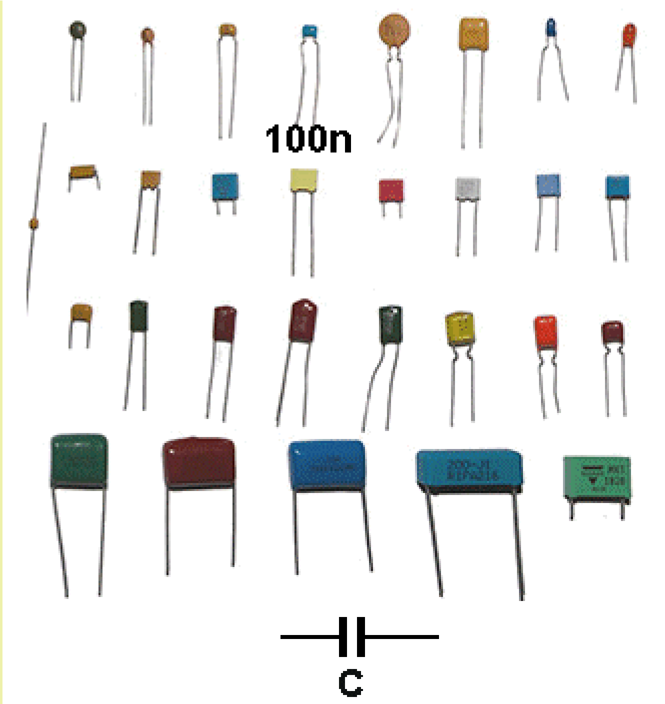
HOW A CAPACITOR WORKS

Home

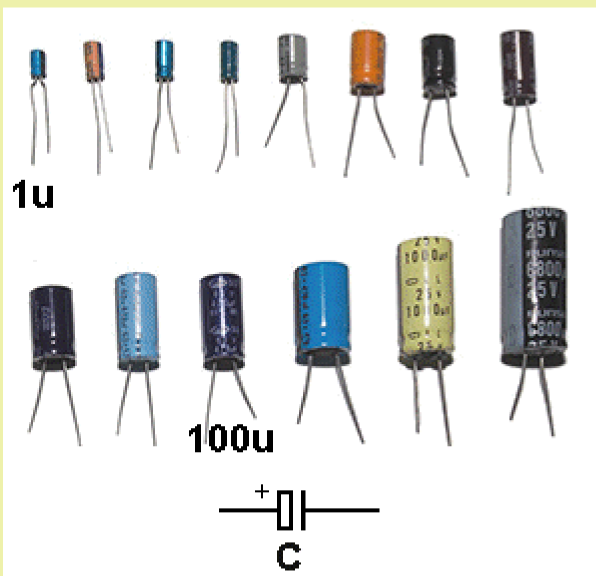
More on the capacitor in: Basic Electronics 1A

There are hundreds of different types of capacitors
THEY ALL WORK THE **SAME**.
They are **ALL similar to a RECHARGEABLE BATTERY**.
A capacitor takes time to charge.
A rechargeable battery takes time to charge.
A miniature rechargeable battery stores 10,000 times more energy than the same-size capacitor, but they are both very similar as they both store "electricity - energy."
Of course there are lots of differences between a battery and a capacitor, but this discussion is designed to simplify **HOW A CAPACITOR WORKS** as some capacitors are "jumping up and down" in a circuit while being charged and discharged while others are just "sitting" and being charged and discharged. It all depends where they are located in a circuit.
Some capacitors pass a signal from one stage to the next (these are "jumping up and down" while others reduce the amplitude of a signal (called smoothing or filtering).
A capacitor takes a period of time to charge (and discharge) and this time is detected by a circuit to produce an OSCILLATOR. It is the basis of a circuit called a TIME DELAY and needs a resistor in series with the capacitor to produce the time delay.
A capacitor can create a waveform OUT OF NO-WHERE when combined with an inductor (coil) and this amazing capability produces another type of oscillator - called a sine-wave oscillator.
In fact a capacitor can perform more than 10 different functions and produce many different effects and that's why you need to read this article so you can determine what each capacitor is "doing" in a circuit.
You may have a circuit with 10 capacitors and each is performing a different function. You need to know what each is doing and if it is "standing still" or "jumping up and down."
That's one of the first things you need to know when looking at a circuit to "see" how it is operating.
When you can "see" a capacitor "rising and falling" you can see how energy it is passing from one lead of the capacitor to the other by looking at the value of the surrounding components.
That's why anyone who draws a circuit without component values ON THE CIRCUIT is not a real electronics engineer. He obviously cannot see a circuit working and that's why the component values are of no importance.
The skill of being able to "see" a capacitor "jumping up and down" in a circuit has never been described before in any text book or covered in any lecture and that's why so few people really understand how a circuit works.
This concept is what makes Tesla, Armstrong and other pioneers so brilliant. They could see the circuit working and they how they "thought-of" and improved the design.
They didn't have any text books to refer-to, they had to invent the circuit.
That's why we have included animations. They show how the capacitor works.

CAPACITOR SAMPLES:



Different types of capacitor and symbol



Electrolytics

PHOTO of capacitor and battery

A capacitor is like a shock absorber in a car. Without a shock absorber, the wheel will move up and down very quickly and the car will bounce up and down. When a shock absorber is fitted, the car glides smoothly.
Thus a capacitor (called an electrolytic) will smooth a rail (a rail voltage) that is jumping "up and down."
This is because a capacitor takes time to charge and discharge.

When a capacitor is combined with a resistor or inductor, other effects can be produced.

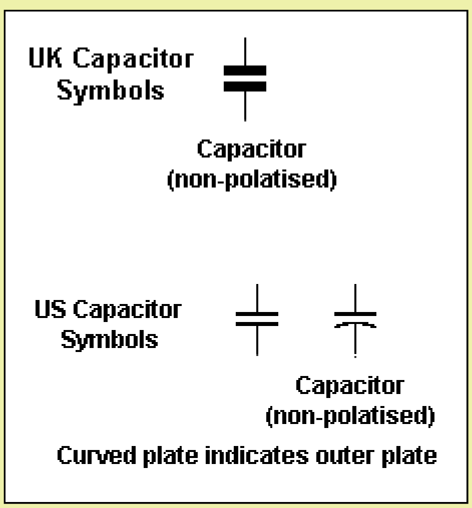
Here are some of the effects:

1. It can charge and discharge slowly via a resistor. This is called a timing circuit or delay circuit. The voltage is detected and amplified to produce a waveform called an oscillation or waveform or oscillator.
2. It can prevent a waveform rising or falling quickly, just like a "shock absorber" in a car. This is called a reservoir capacitor or "spike prevention" capacitor.
3. It can pass a waveform from one part of a circuit to another. This is called a coupling capacitor.
4. It can produce a waveform (called a sinewave) when connected to a coil (called and inductor).
5. It can store energy and release it when required. This is called a reservoir capacitor (electrolytic).

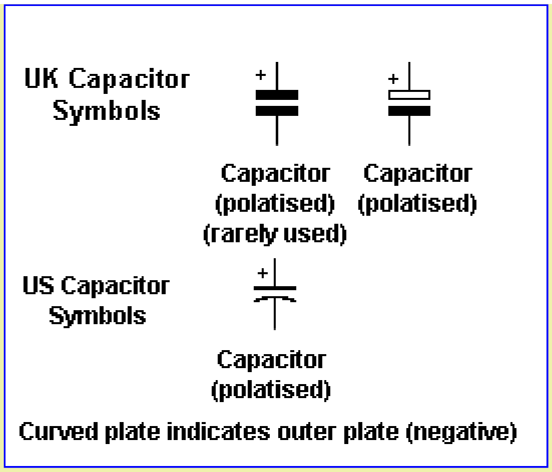
In other words, it can do lots of things and that's what we will study.

CAPACITOR SYMBOL

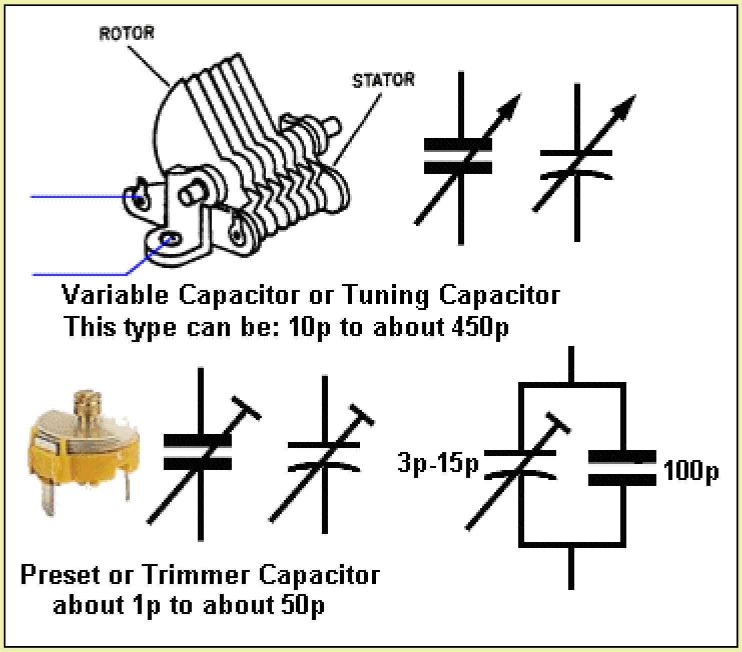
The symbol for a capacitor is two parallel lines with a space between the lines. This is exactly what a capacitor is: two plates that do not touch. There are slightly different variations on this to show a "normal" capacitor (generally a capacitor from 1p (1 picrofard) to 1 microfarad - 1u and made by interleaving aluminium foil between paper, plastic or mica). These are also called non-polarised capacitors because they can be fitted to a circuit around either way.
A polarised capacitor must be fitted so the positive lead sees a positive voltage to keep the oxide layer inside the capacitor in good condition.



NON-POLARISED CAPACITORS



POLARISED and ELECTROLYTIC CAPACITORS



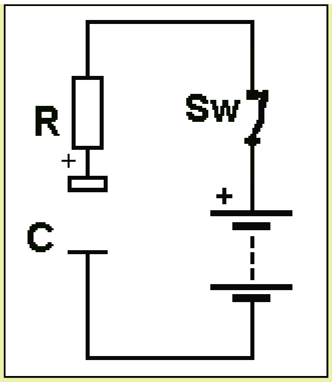
VARIABLE CAPACITORS

An electrolytic is a capacitor has the aluminium foil etched to increase the surface area by up to 100 times and a liquid (electrolyte) is added to contact this surface to produce the high capacitance.

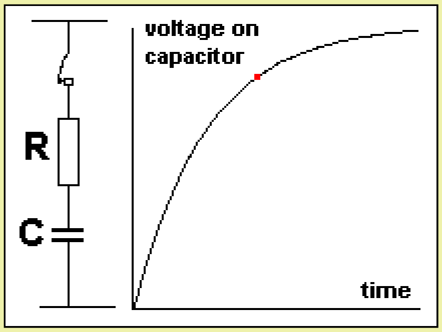
A capacitor can work on its own as a **STORAGE** or **RESERVOIR capacitor** (as explained in 3 below) or operate with a series resistor.
When a resistor is in series with a capacitor, the capacitor will take a period of time to charge and discharge.
From this you can work out what is happening to the signal at the join of the two components.
Here is how the slow-charging and slow-discharging works:

CHARGING A CAPACITOR

A battery and a capacitor are very similar. They both take time to charge.
In most circuits a capacitor is connected in series with a resistor and this makes the capacitor charge slowly.
As the capacitor charges, the voltage across it INCREASES but the increase is not linear. The voltage increases quickly at the beginning but gets slower and slower.
This looks like an amazing effect but it is really due to the voltage on the capacitor giving the incoming voltage less "pressure" to charge it.
It is just like a man eating 15 hamburgers. He is quick at the start but after the 13th hamburger, his full stomach slows down the eating process.



The capacitor charges to nearly the voltage of the battery



CHARGING A CAPACITOR

The time scale is the X-axis and if you get a perpendicular ruler and move it across the graph at a constant speed, you will find the voltage rises very quickly at the start and slows down as the voltage on the capacitor increases to almost supply-voltage.
As the voltage on the capacitor rises to almost the voltage of the battery, the increase gets slower and slower.
There is nothing magic about this.
The voltage on the capacitor is initially zero and the rail voltage will initially deliver a high current and thus start to rapidly charge the capacitor, as the voltage on the capacitor increases, the difference between the rail voltage and the capacitor-voltage gets smaller and smaller and thus the current entering the capacitor gets less and less and thus the increase slows down.
You don't have to worry about this.
Just remember a capacitor takes time to charge (and discharge).

1b. DISCHARGING A CAPACITOR

The discharge time for a capacitor is exactly the same as the charge-time. If it take 5 seconds for capacitor to charge from 1v to 7v, it will take 5 seconds to discharge back to 1v.
The discharge curve is shown in the following diagram:

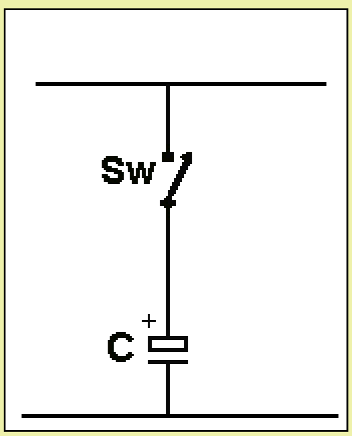
2. THE DELAY CIRCUIT

Here is a circuit using a capacitor (electrolytic) to produce a **DELAY**. The LED illuminates 2 seconds after the power is applied. This is a "speeded-up diagram:

Delay circuit

3. THE RESERVOIR CAPACITOR

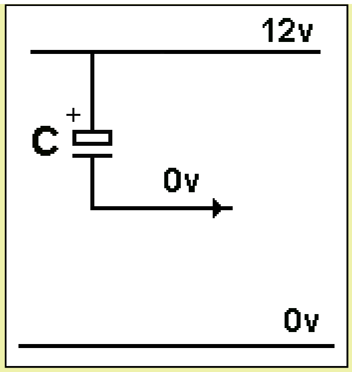
A capacitor can be used to reduce the oscillations on a supply rail.
The capacitor takes time to charge and discharge and it also stores energy when the voltage on the supply rail is HIGH and delivers energy when the supply rail is LOW.
This produces two results. The frequency of oscillation of the supply-rail will reduce and the amplitude of the oscillations will reduce.
This is called STABILIZING the supply rail.
It is also called TIGHTENING UP the supply rail.
It reduces the HUM in audio amplifiers.
It reduces the spikes and glitches in digital circuits.
It is also called the FILTER capacitor.
It is also called a DECOUPLING capacitor as it prevents a spike or glitch from one section of a circuit reaching another section.
A reservoir capacitor (electrolytic) has a HIGH VALUE so it has the greatest effect on reducing fluctuations.



A RESERVOIR electrolytic

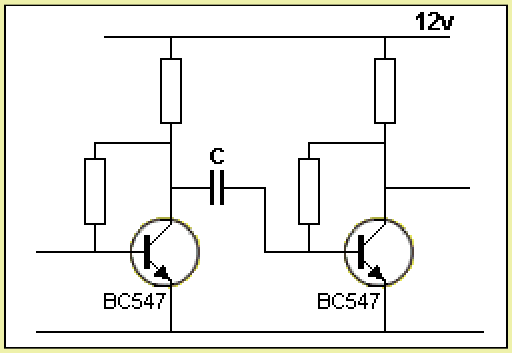
4. A CAPACITOR SEPARATES TWO STAGES

(in other words: A Capacitor blocks DC - it does not allow energy to pass from one plate (lead) to the other)
The symbol for a capacitor is two lines with a space between. This means one plate is NOT connected to the other.
If you connect 12v to one of the plates, NO VOLTAGE will appear on the other plate, as shown in the diagram. This diagram is showing that the capacitor will not deliver any energy from the lead identified with an arrow. If you connect anything to the lead, the capacitor will charge and give a "spark" or pulse of energy BUT when it is fully charged, it will not deliver any more energy from the lead. This is because the two plates are not touching each other.



Read the text above to understand this diagram

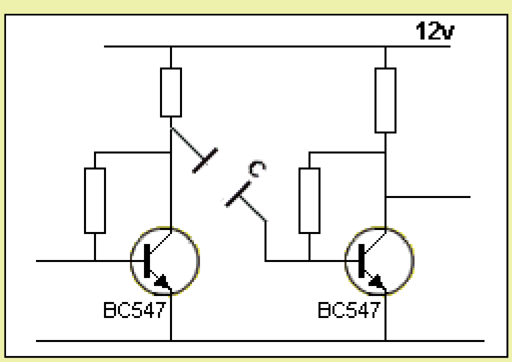
Here is a circuit with a capacitor separating two stages:



The voltage on the collector of the first transistor is about 6v and the voltage on the base of the second transistor is about 0.6v.
These voltages are produced by the transistors and surrounding resistors. You cannot connect these two points directly as the voltages are different. If you connect them directly, the circuit will NOT WORK.
The capacitor connects these points and allows the signal from the first stage to pass to the second stage, while keeping the 6v separated from the 0.6v.
In other words: The Capacitor is **BLOCKING DC**.

How does the capacitor pass a signal?
It works just like a magnet on each side of a door. If you raise the magnet on one side, the other magnet rises too.
If you raise the left lead, you increase the gap between the two plates and energy flows into the right lead to fill the gap. The components connected to the right-lead see this as a voltage almost identical to what is happening to the left lead.
This is obviously only a simply way to see the circuit working, but this is how you visualise what is happening.

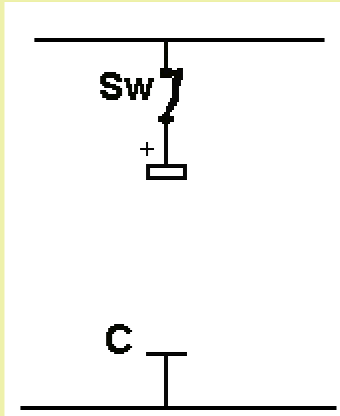
Here it is:



When an electronics engineer looks at a circuit, he sees the capacitors (and electrolytics) "jumping up and down" or "charging and discharging."

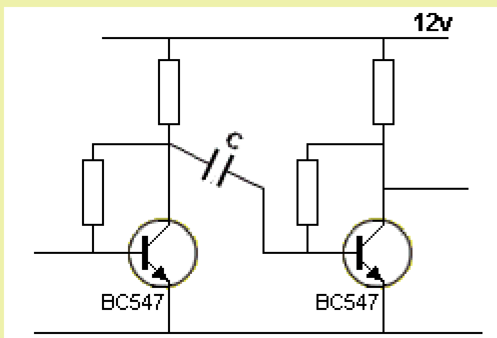
HOW DOES HE SEE THIS ???

1. If a capacitor has the negative lead connected to the 0v rail, it will charge and discharge:



This capacitor does not jump up and down.
It just charges and discharges

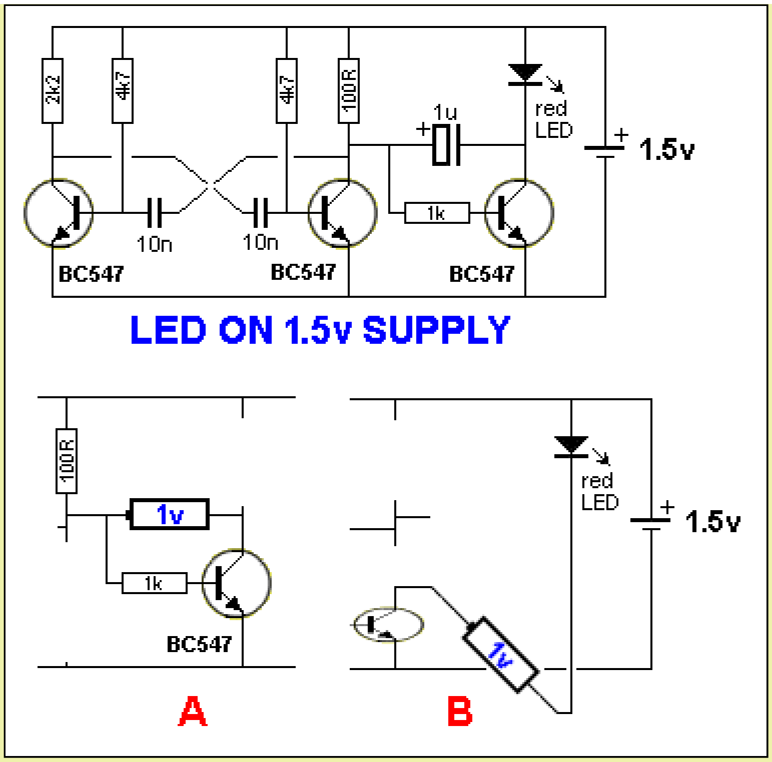
2. If a capacitor is NOT connected directly to the 0v rail, it will JUMP UP AND DOWN.



This capacitor jumps up and down

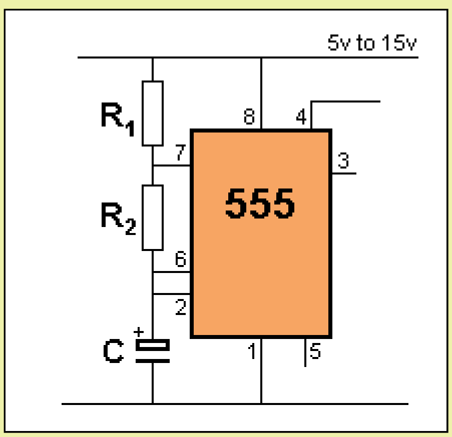
In other words, the positive lead on the capacitor will receive a signal and the capacitor will start to charge. Because the negative lead is not connected to the 0v rail, it will also rise and this will make the whole capacitor "rise" in the circuit.
During this time the voltage across the capacitor will increase and when the signal on the positive lead reduces, the capacitor will "fall" The voltage on the negative lead can actually go below the 0v rail and that will be a surprise to many readers.

Here is a capacitor (electrolytic) "jumping up and down" to increase the voltage to more than 1.7v to illuminate the LED.

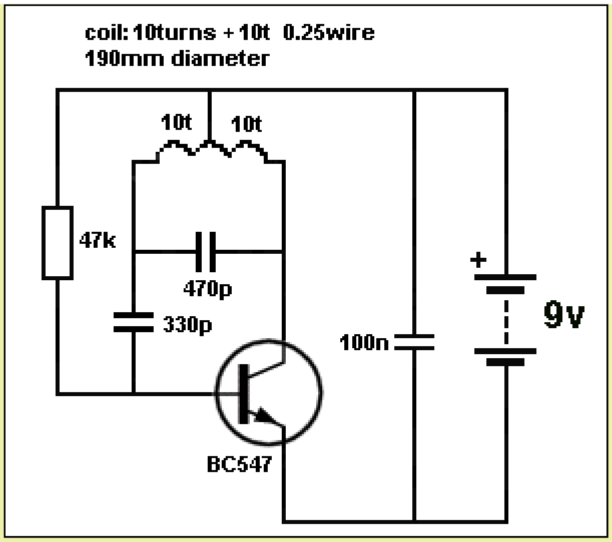


The 1u electrolytic is charged via the 100R and the collector-emitter of the third BC547 when it is turned ON. When the multivibrator changes state, the second transistor is turned ON and the left-lead of the 1u is pulled towards the 0v rail.
This takes the right-lead DOWN and the 1u acts like a battery of about 1v. The right lead goes BELOW the 0v rail by about 1v and the LED see 1.5v on its anode and -1v on its cathode. This makes a total of 2.5v across the LED. But the LED only allows a voltage of 1.7v to appear across its leads and thus it turns on to produce a bright flash.

The following diagram shows a timing circuit made up of C and two resistors. When the capacitor charges to 2/3 of the voltage on the supply rail, the 555 turns ON and starts to discharge the electrolytic. This capacitor does not "jump up and down" because it is connected to the 0v rail.



Here is an oscillator circuit using a capacitor. It is a metal detector that operates at about 100kHz and when a piece of metal is placed near the coil, the frequency of the circuit decreases.
There are 4 capacitors. The 330p is moving up and down a very small amount because the voltage on the base does not alter very much.
The 470p also moves up and down (sideways) by a large amount because it is across the output of the coil and this is a sinewave with an amplitude of about 16v. The 100n does not move up and down because one lead is connected to the 0v rail.



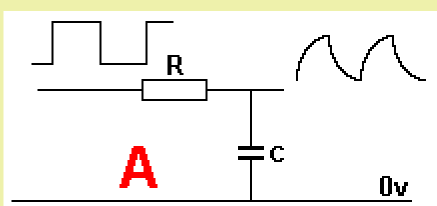
By knowing how much a capacitor jumps-up-and-down, you can "see" a circuit working.

THE CAPACITOR AS AN INTEGRATOR

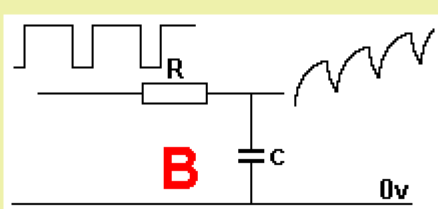
(in other words: A Capacitor accumulates pulses)
An Integrator is a "collector of pulses."

An INTEGRATION circuit basically takes a high voltage pulse and produces a lower voltage pulse with a wider duration.
It works like this: The energy of a pulse is the area under the pulse as shown in the diagram and this areas is spread out into a wider format with a lower height.
The shape of the resulting waveform depends on the shape of the pulses. Remember the fact that the incoming waveform charges the capacitor according to the curve above and discharges it when the input is low.
If the input consists of s number of pulses, the result can be a small DC voltage this DC may trigger another circuit.
In many cases an INTEGRATOR circuit is designed to produce and output when a number of pulses in rapid succession are detected, and neglect individual stray pulses.

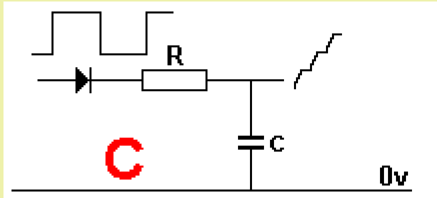
A INTEGRATION circuit accumulates the incoming pulses, but the pulses must be the right shape for this to occur.
In the case of **circuit A**, the square wave has a HIGH equal to the LOW and the capacitor charges during the HIGH and discharges during the LOW. The result if integration is not produced.



In **circuit B**, the HIGH has a longer duration than the LOW and the capacitor charges during the HIGH and does not have time to fully discharged during the LOW. This means the capacitor will gradually charge more and more after each pulse.

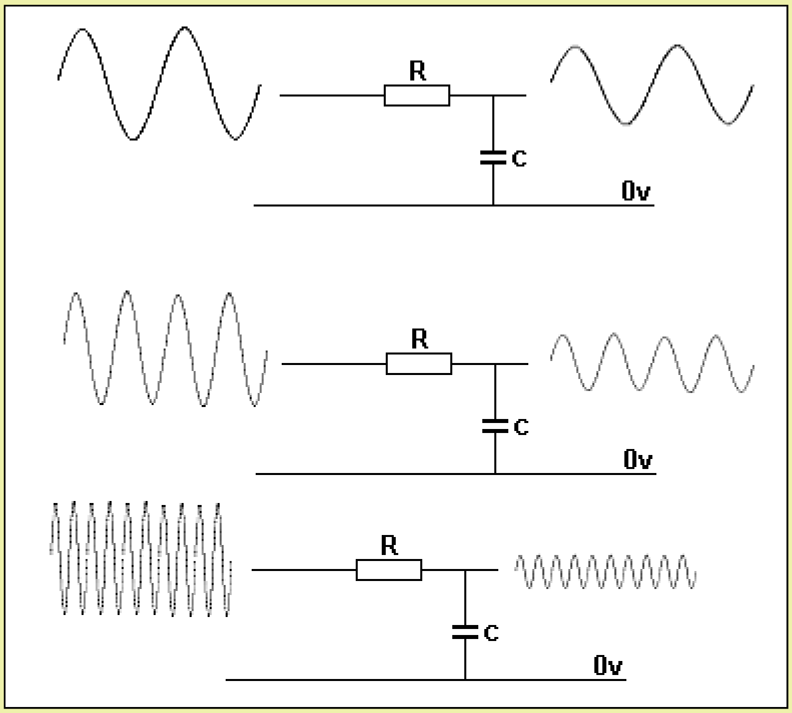


In **circuit C**, the "steering diode" prevents the capacitor discharging during the LOW and it gradually charges more and more after each pulse, even though the incoming waveform has an equal HIGH and LOW period.



AN INTEGRATOR CIRCUIT IS A LOW PASS FILTER

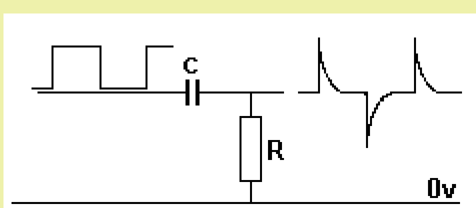
In other words, the circuit only allows a low frequency to pass. To put it another way, a high-frequency signal is ATTENUATED or REDUCED. In the following three diagrams, the incoming frequency is increased and you can see the output amplitude decreases.



As the frequency INCREASES, the output amplitude DECREASES

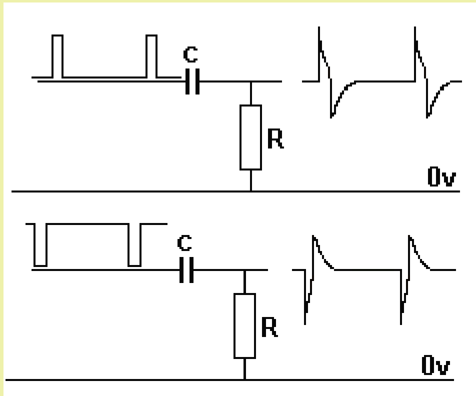
THE CAPACITOR AS A DIFFERENTIATOR

A differentiator only passes HIGH FREQUENCY signals.



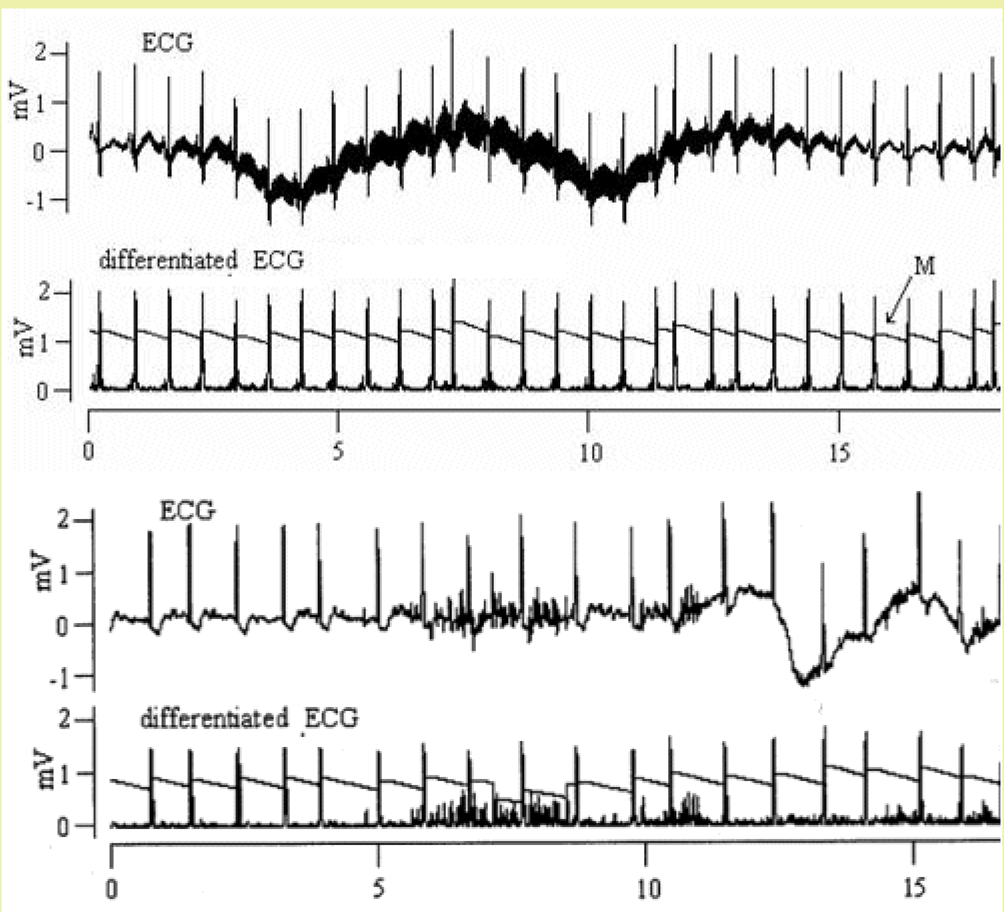
The word "passes" doesn't mean the output of the differentiator is the same as the input. It means the output signal from a high frequency will have a good amplitude and the signal can be recognised and can be process further.
A Differentiator only passes high frequency signals because if a low-frequency signal is delivered to the capacitor, it will charge via the resistor and the right-hand lead will remain at 0v. A low-frequency signal is not a square-wave but a sine-wave or an audio wave that rises and falls very slowly and the frequency of the signal is low for the value of capacitor and

resistor used in the circuit. The circuit is not acting as a differentiator for sine-waves.
When a square-wave is delivered to the capacitor, the output will peak for a very short period of time then fall, as the capacitor charges.
When the waveform drops to 0v, the charge on the capacitor creates a NEGATIVE voltage on the output and it can go BELOW the 0v rail by an amount almost equal to the amplitude of the square-wave.



The output of a DIFFERENTIATOR

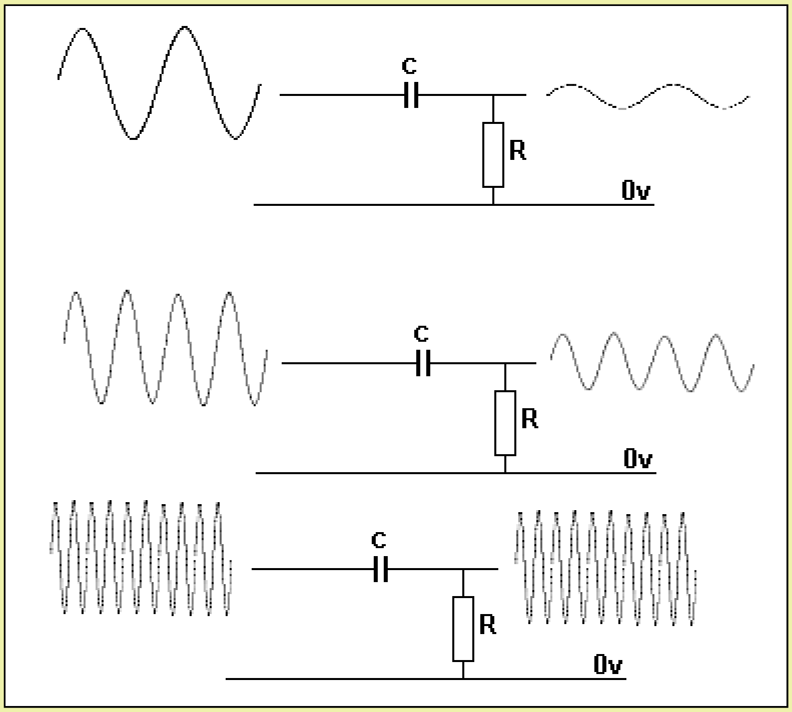
What is the purpose of a DIFFERENTIATOR?
Suppose we have a very noisy signal from the electrodes measuring the electrical activity of the heart. This is commonly called an electromyogram signal, as shown in the following charts:



The part of the signal that we want to work-on (and amplify) is the spikes. After differentiation, these spikes have a common height and an additional circuit can detect them to produce a "heart-beat-rate." A lot of the noise has been eliminated.

A DIFFERENTIATOR CIRCUIT IS A HIGH PASS FILTER

In other words it only passes high frequency signals.



As the frequency INCREASES, the output amplitude INCREASES

As the frequency INCREASES, the output amplitude INCREASES. With a high frequency, the voltage on the let-lead of the capacitor is rising quickly and the capacitor does not have time to charge via the resistor R. This means the voltage on the left lead is the same as the right lead and thus the output has the same amplitude as the input.
With a low frequency, the capacitor has time to charge via the resistor and some of the amplitude of the signal is developed across the capacitor and this amount (height) of the signal does not appear on the output. Thus the output has a lower amplitude.

A CAPACITOR PRODUCES A SINEWAVE

If you place a capacitor and resistor in series and apply a voltage at the connect instant and remove it at the right time, the waveform produced at the intersection of the two components is very similar to a sinewave.
This knowledge will help you understand what will appear at the join of a resistor and capacitor when a pulsing, or square wave is delivered. The result is a much-smoother version of the waveform.
That's what the capacitor does. It slows-down the rise and fall of the waveform to produce a smooth output.

A CAPACITOR "JOINS" TWO STAGES

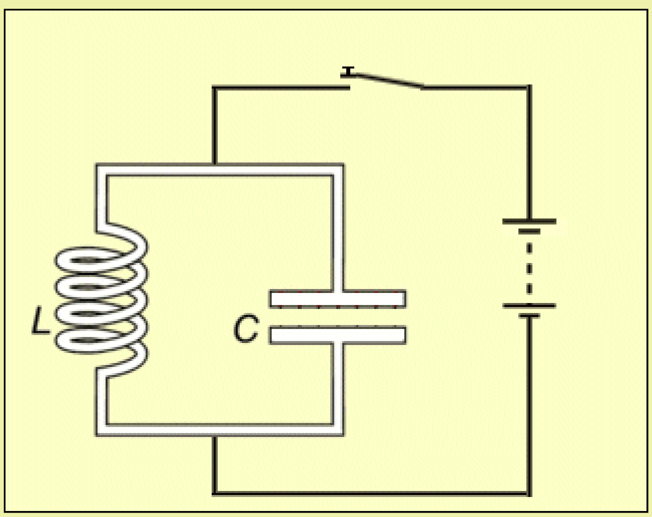
A capacitor can be used to "join" two stages. A STAGE is a transistor and surrounding components to allow the transistor to operate so it is not overloaded.
The signal enters the left-side of the stage and emerges on the right.
The stage might amplify the signal or invert it or change the shape.
This state will be connected to a previous stage and a following stage to amplify the signal more or perform other requirements.
Sometimes one stage can be connected to another. This is called DC coupling (DIRECT COUPLING) but sometimes the stages CANNOT be directly coupled because the output voltage on the previous stage will be large and the input voltage on the stage we are studying must be very small because the transistor can only handle small voltages on the input.
In other words the AMPLITUDE of the voltages (the SIZE of the voltages) must be kept separated.
This can be done with a capacitor.
There are two interesting points to note:
The voltage on the left-lead of the capacitor consists of two components.
The voltage will consists of a DC component. This time the letters DC refer to the words

DIRECT CURRENT and really mean the value of voltage that a battery would supply.
That's why we use the letters DC. Because we really mean "battery voltage." That's why you have to learn ELECTRICAL TERMINOLOGY.
The voltage on the left-lead will also consist of a rising and falling voltage. This is called the AC voltage or waveform.
The letters AC refer to ALTERNATING CURRENT but we just say the letters "AC" because we really mean "WAVEFORM."
So, the voltage on the left-lead consists of two components (two different values) AC and DC.
The capacitor will block (NOT allow the DC components to pass from the left lead to the right lead) the DC component and allow the AC (the waveform) to pass.
The resistor is this:
The right-lead on sees the WAVEFORM.
The transistor in the stage we are studying can now amplify this waveform.
That's how an amplifier works.

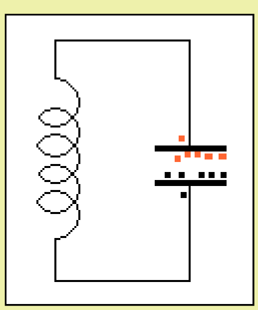
THE TUNED CIRCUIT (TANK CIRCUIT)

When a capacitor and coil are connected in parallel and given a short pulse of energy, they send this energy back and forth between the two components. The capacitor is initially charged and it passes this charge to the coil to produce magnetic flux. When the capacitor can no-longer keep increasing the flux from the coil, the magnetic flux start to collapse and produce a voltage in the opposite direction that charges the capacitor in the opposite direction. This continues until the flux can no-longer keep increasing the voltage on the capacitor and then the the capacitor sends out its voltage to produce magnetic flux in the opposite direction (meaning the north and south poles are reversed). When the magnetic flux can no-longer be kept at an increasing level, the flux starts to collapse and produce a voltage in the opposite direction that charges the capacitor in the original direction to repeat the cycle.

Here is how the initial charging occurs:

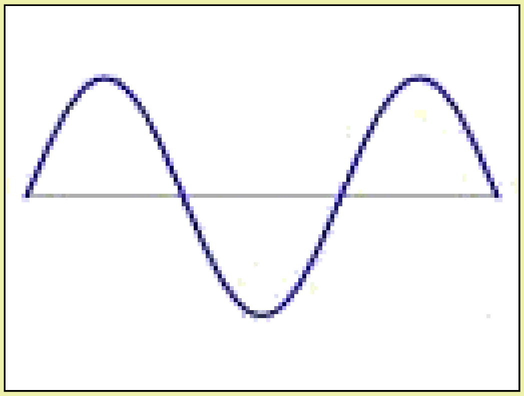


Here is how the charge continues around the circuit:



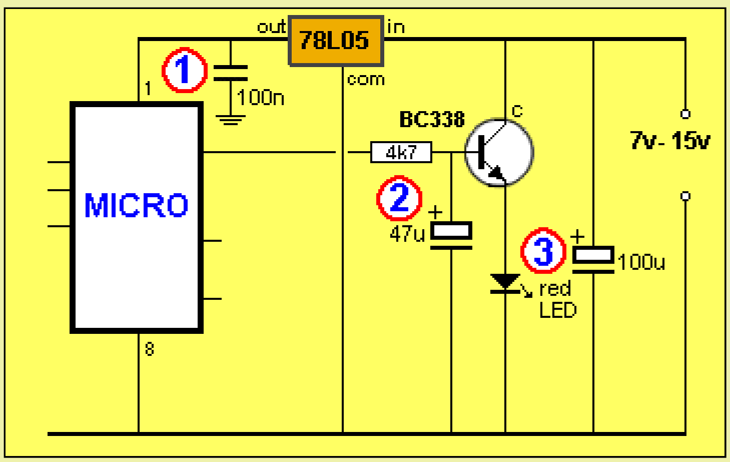
The animation above is about the closest you will get to understanding how the energy transfers from the capacitor to the coil and back to the capacitor aging.
The amplitude will get smaller and smaller due to losses and the switch must be closed for a

very short period of time AT THE RIGHT INSTANT for the circuit to work.
However the result is an amazing sinewave:



THE CAPACITOR IN A CIRCUIT

In the following circuit we see three different capacitors in different situations (different applications - different reasons and different outcomes).
This is a practical application for a capacitor and here is the reason why they are used and how the value is chosen.



Capacitor 1 is 100n. (0.1u) and is placed near the power rails of the microcontroller (or any IC) to prevent noise on the supply rail entering the chip.
The capacitor also prevent any pulse produced by the chip entering the supply rail and passing to other chips.
These pulses have a very short duration and are classified as high frequency. A 100n capacitor will have an effect on reducing this type of pulse.
This capacitor also produces an effect called: "tightening the power rails" and effectively acts like a miniature battery with very low impedance supplying current to the chip. This effect (improvement) is very noticeable in high frequency circuits and 22n to 100n will make an enormous difference in a circuit operating at 100MHz.

Capacitor 2 is placed on the base of the transistor and when the transistor is turned ON via the 4k7 resistor, it gradually charge. This causes the LED to gradually illuminate.
When the output of the micro is LOW, the capacitor gradually discharged and the LED gradually dims.

Capacitor 3 is placed across the battery to prevent the battery voltage dipping when the circuit requires pulses of current.
These pulses of current can be 2 to 10 times more than the average current taken by the circuit and when the battery gets slightly depleted, it cannot deliver this current without the voltage dropping noticeable.
This dip in voltage will be sent to all the chips in the project and may upset some of the waveforms.
This is especially noticeable in audio circuits where "pulses" or "glitches" passed to the front-end of an amplifier will be amplified and re-sent back to the front-end in a loop called

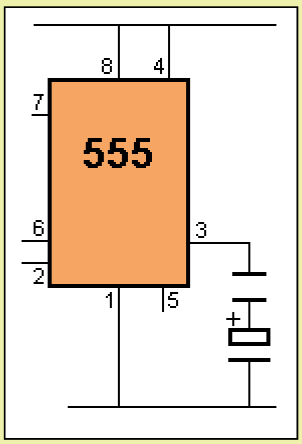
"feedback."
This feedback is detected as "motor-boating" or "putt-putt-putt" from the speaker.

HOW A CAPACITOR CHARGES IN A CIRCUIT

Just because a capacitor charges and discharges in a circuit does not mean every capacitor is "acting" the same. Some capacitors are "jumping up and down," others are charging more than another capacitor and others are producing a negative voltage.

Here are three capacitors connected to the same output of a 555 where the output is changing from LOW to HIGH very quickly and remaining HIGH for a period of time before returning to LOW. These diagram are not completely accurate but give an idea of the capacitor charging and discharging and the animation highlights the different effects when other components are connected in series with the capacitor.

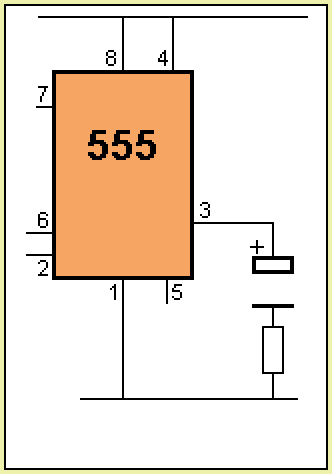
ANIMATION 1:



The smaller capacitor charges to a higher voltage than the larger capacitor and at no time is any lead of a capacitor taken to below the 0v rail. (See the next animations for a negative-effect).
This effect takes a lot to understand and MANY electronics engineers get it wrong.
The explanation is as follows: A capacitor has the amazing ability to change a charge consisting of a high voltage with a small current into a low voltage and high current.
Firstly we will explain what we mean: We can charge a huge electrolytic, such as 100,000u to a voltage of say 200v over a period of 5 minutes with a small current such as 200mA.
We can now get a spanner and short the two terminals and get an enormous spark that welds the spanner to the contacts.
This welding process is due to the enormous current.
But we only charged the electrolytic with 200mA.
The electrolytic has changed the energy it has received from a value of 200v and 200mA into a few volts and 100 amps.
That's what ANY capacitor can do in ANY circuit and it all depends on the value of the surrounding components.
If we take the animation above, the output of the 555 delivers a voltage and a current to the two capacitors in series. Since they are in series, the current through the top capacitor must be the same as the bottom capacitor.
So, we cannot talk about different current-values.
This is the only way we can explain it: Water is flowing out pin3 of the 555 and half of it flows into the small top capacitor to fill it very quickly while the other half flows into the large electrolytic and it rises on very slightly.
When pin3 goes LOW, it is exactly the same as connecting the top capacitor to the 0v rail.
The charge flows out of the capacitors at the same rate as they were charged. In other words, both capacitors will discharge smoothly but the discharge-time may be a lot quicker than the charge-time.

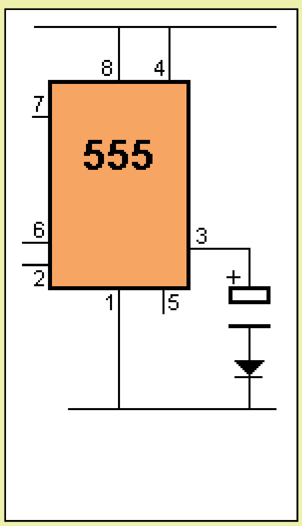
ANIMATION 2:

The following animation shows the electrolytic charging via the output of the 555. The output actually rises very quickly and this animation would be correct if the output rises slowly.
The point to note is this: The negative lead of the electro drops below the 0v rail when the output goes LOW and the electro is discharged via the resistor.



ANIMATION 3:

When a diode is connected in series with the electrolytic, it gets fully charged on the first cycle and the negative lead goes below the 0v rail when the output of the 555 goes LOW. The electrolytic remains charged and does not get discharged by the diode.



The electro does not discharge

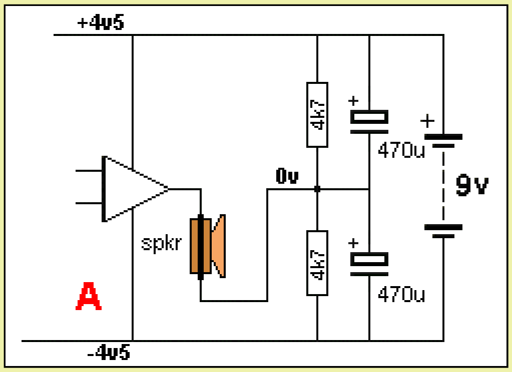
SPLIT RAIL

Here is another circuit that requires a special way of thinking to "see" how the electrolytics work.

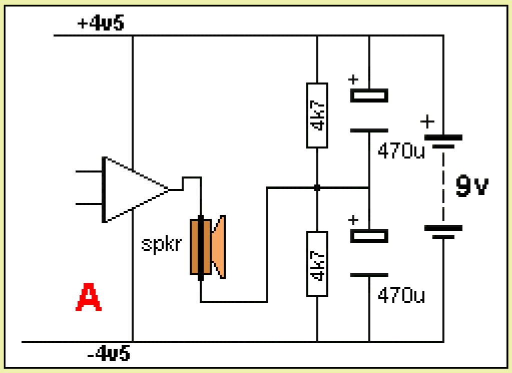
Some circuits need a voltage that is identified as 0v voltage at a particular connection and a positive voltage and a negative voltage.
The reason for this is the output of the circuit has a voltage that is half-way between the voltage on the top rails and the bottom rail and it produces a signal that rises almost as high at the top rail and almost as low as the bottom rail.
This means the amplifying circuit, such as an op-amp or AMPLIFIER, requires a voltage that is equally POSITIVE and NEGATIVE, with the earth, or chassis or neutral classified as having zero voltage. In other words it is the reference point (0v) for all the other voltages.

As far as the output is concerned, the two 470u electrolytics are connected in PARALLEL and prevent the bottom lead of the speaker moving, when a signal is delivered to the top lead.
The do not prevent the bottom lead moving like a fixed connection but limit the movement or

restrict the movement just like a 2 ohm resistor.
A 100Hz, the two 470u electrolytics have a resistance (impedance) of slightly less than 2 ohms and at a higher frequency this value is a lot less. That means most of the signal will appear across the speaker.

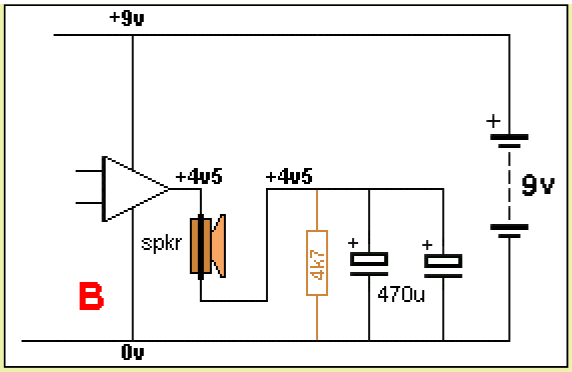


Producing a SPLIT-RAIL SUPPLY



The electros charging and discharging

When the signal from the amplifier rises to a HIGH, the speaker sees nearly all the amplitude. Both the 470u electros try to hold the bottom lead of the speaker in a fixed position but one of them charges and the other discharges slightly. This action is reversed when the signal moves in the opposite direction.
You can see one of the electrolytics is charging and this is easy to understand. But the other electro discharges at the same rate and it produces the same effect on the lead of the speaker in trying to keep it from moving.
An electrolytic is exactly the same as a shock absorber containing oil and the oil is passed from one cylinder to another via a very small hole. You can press very slightly on the shock absorber and it will open or close completely. This is the action of the 4k7 charging the electro over a long period of time.
But if you push very hard on the shock absorber, it will only move very slowly. This is the action of the signal (via the speaker) on BOTH electros.
It does not matter if you are charging the electro or discharging it. The same "resistance to movement" or resistance to charging/discharging, applies.
Because the positive rail are classified as "unmovable" the positive end of the top electro DOES NOT MOVE and the negative of the bottom electro DOES NOT MOVE.
Because these ends do not move, the top electro can be taken to the negative rail and it will have the same effect.



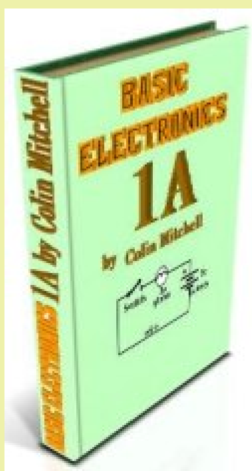
The electros can be placed on the negative rail to deliver the same effect as creating a Split-Rail

The end result of the 2 x 470u electrolytics is exactly the same as placing them in parallel to produce 1,000u. The diagram above shows the circuit re-arranged with the two electros on the negative rail.
The amplifier will produce an output swing of +4.5v to -4.5v and charge/discharge the two electros so they will produce exactly the same result as in the first circuit.

You will find a lot of helpful material on these pages:

Spot Mistakes: P1 P2 P3 P4 . . P11 P12 P13 P14
P15 P16 P17 P18 P19 P20

Now go to Basic Electronics 1A:



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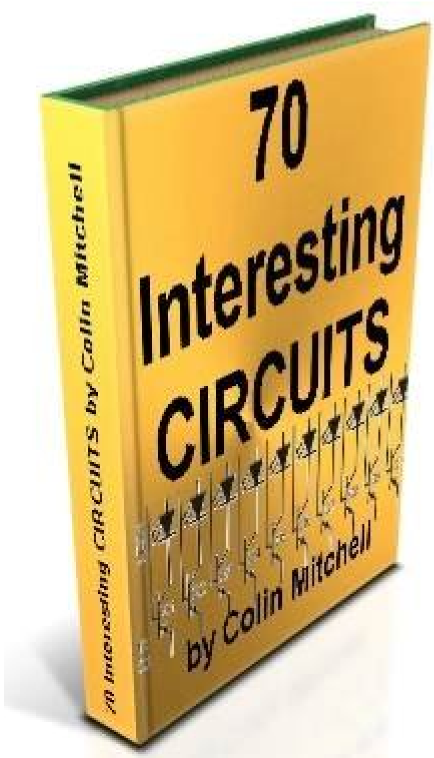

Talking Electronics

See TALKING ELECTRONICS WEBSITE

email Colin Mitchell: talking@tpg.com.au

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1 - 100 Transistor Circuits
101 - 200 Transistor Circuits
100 IC Circuits

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INTRODUCTION

This e-book covers a number of interesting

circuits.
They have been presented for a reason.
The original circuits come from an Indian Electronics Magazine and most of them had faults. Either they were over-designed, poorly designed or contained a fault.
In the process of bringing these faults and corrections to you, we have created this eBook of **70 Interesting Circuits**.
You can lean a lot from other peoples mistakes. Not only will you remember not to make the same mistake but the corrections and improvements generally require less components.
The art of designing a circuit is to make it as simple as possible and use the least number of components.
But before you put a design into production, get someone else to look at it.
Another "set of eyes" will see things differently and maybe simplify or improve the design.
We have already presented a set of pages called "Spot The Mistake," showing dozens of faulty circuits and how to check and test things before releasing them. It is surprising that a magazine with a readership of over 1,000,000 could publish items with glaring faults.
The faulty projects in this collection have a revised circuit included in the article and you can compare the two designs. It only takes a minute to see a circuit will not work and a few more minutes to create a improved design.
This is what we are teaching in this section . . . how to look at a circuit with a "critical eye" then design an improvement.
This is called REVERSE ENGINEERING and involves the highest level of technical skill.
But it is also the fastest way to test a persons skill and the fastest way to learn.
That's why I consider it to be the most important approach to learning.

Colin Mitchell
TALKING ELECTRONICS.
talking@tpg.com.au

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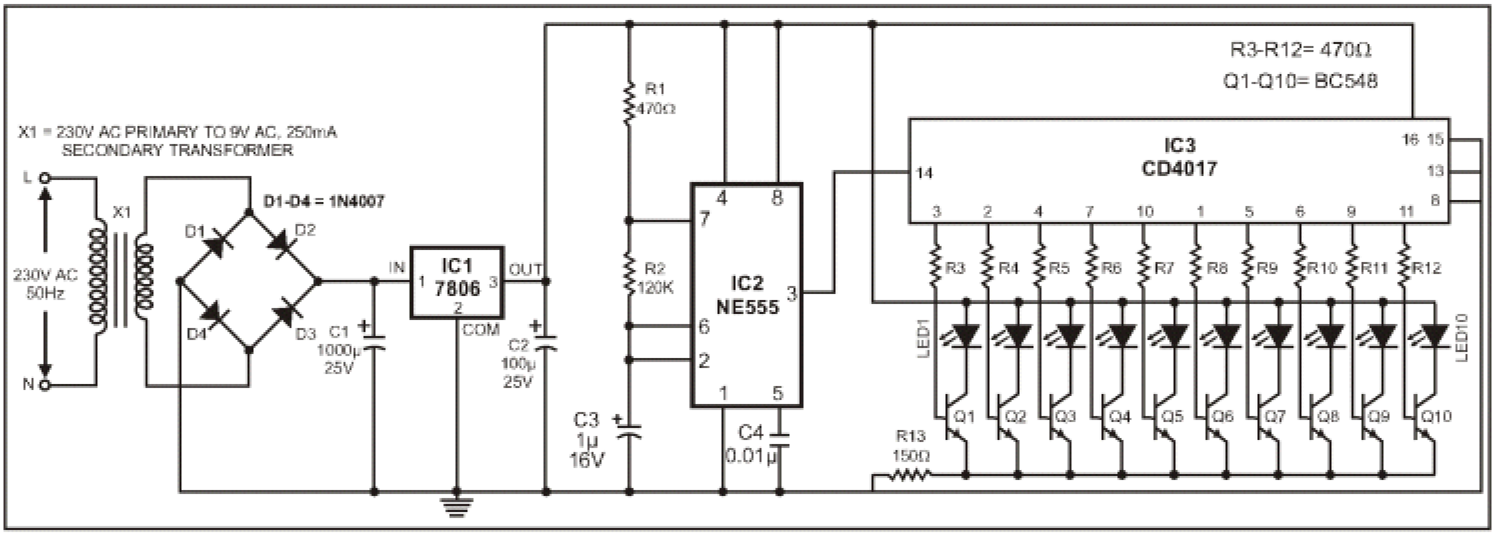
10 OUTPUT LED SEQUENCER

Here is 10 output LED sequencer. After the last LED is illuminated, the circuit is reset. This circuit is build around readily available, low cost components - a 555 and decade counter CD4O1 7. The timer IC NE555 is wired as an astable multivibrator that produces 6Hz clock at its output pin 3. The 4017 is a CMOS decade counter with 10 outputs. Inputs include a CLOCK (Pin 1 4), a RESET (Pin 15), and a CLOCK INHIBIT (Pin 13). The clock input connects to a Schmitt trigger for pulse shaping and allows slow clock rise and fall times (not needed in our case).

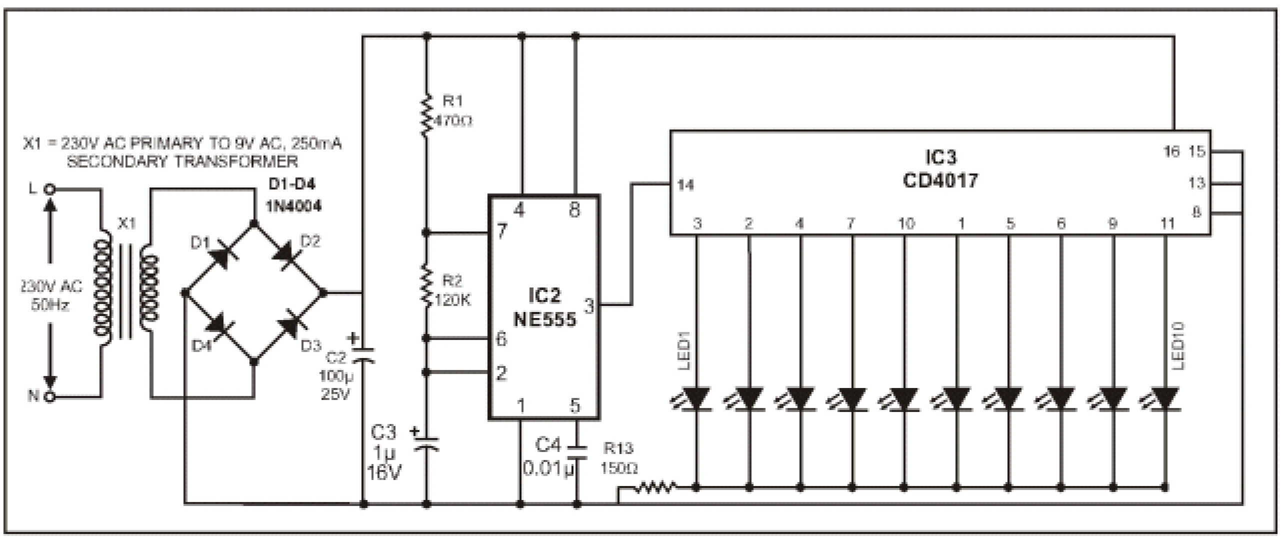
The counter advances one output at the rising edge of the clock signal if the CLOCK INHIBIT line is low. A high RESET signal resets the counter to the zero output. The circuit may be configured for counts less than 10 by connecting RESET to an output pin (one after the desired count). Thus, a five stage sequencer can be made by connecting pin 15 to pin 1. A CARRY-OUT signal (pin 12) can be used to clock subsequent stages in a multi-device counting chain.

The output from 1C2 pin 3 is connected to clock pin (pin 14) of the IC3 for sequencing operations. NPN transistors Q1- Q10 are used to increase the output current for the LEDs which is set by the common 150 ohm resistor. In the circuit, only one of the outputs is HIGH at any one time and the output advances by one count with every clock pulse.



Circuit Diagram of 10 Stage LED Sequencer

But the circuit above is poorly designed.
It does not need the voltage regulator as both chips can work up to 15v.
The 4017 can supply 10mA to a LED on a 12v supply so that none of the transistors are needed.
The circuit below shows the necessary components.
The secret to designing a circuit is to look at the final design and ask: "is this component necessary?"
Try removing a component and see if the circuit still works. Keep doing this with all the components. The circuit above was published in an Indian magazine with over 1,000,000 readers. The faults were obvious. How these faults passed an editorial committee is beyond me. They are showing very poor design-leadership in allowing this oversight to be published. The faults are technical but are obvious to anyone who has constructed the circuit and experimented with it. Obviously the circuit has never been assembled with anyone with technical expertise.



Circuit Diagram of 10 Stage LED Sequencer

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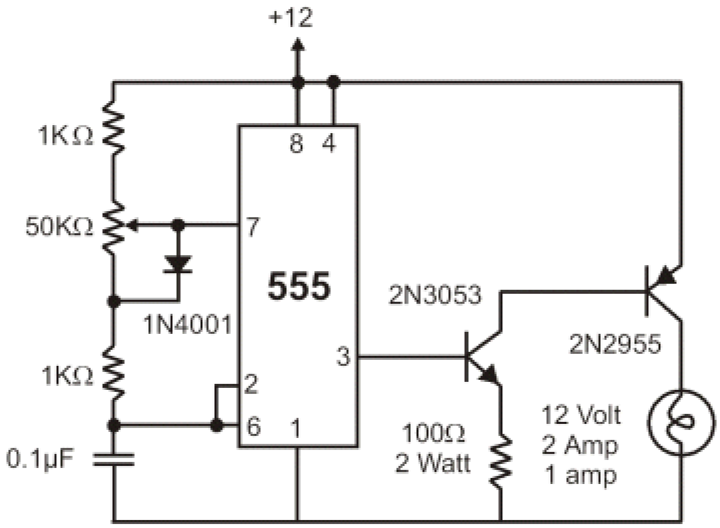
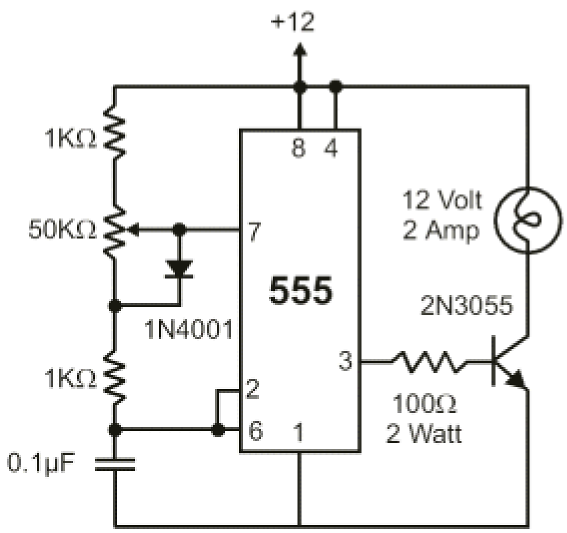
12v LAMP DIMMER

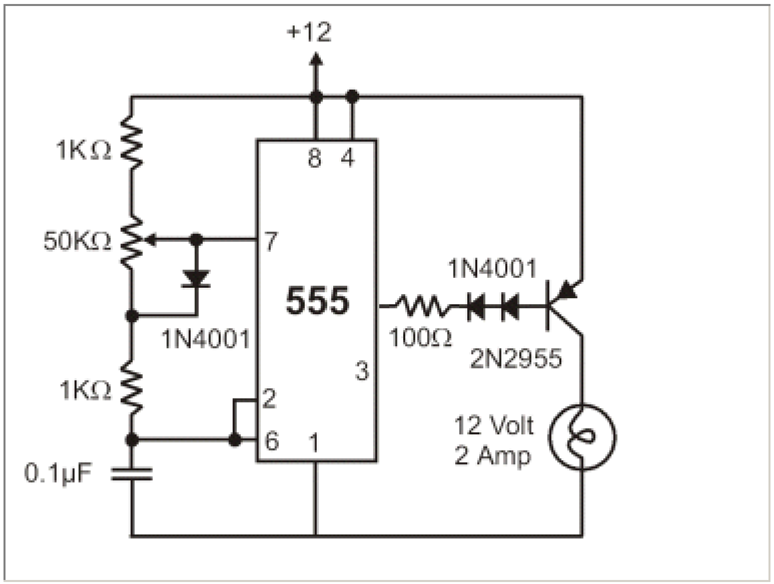
Here is a 12 volt @ 2 amp lamp dimmer that can be used to dim a standard 25 watt bulb by controlling the duty cycle of a astable 555 timer oscillator. When the potentiometer is at the up position, the capacitor will charge quickly through both 1k resistors and the diode, producing a short positive interval and long negative interval which dims the lamp to near darkness. When the potentiometer is at the lower position, the capacitor will charge through both 1k resistors and the 50k potentiometer and discharge through the lower 1k resistor, producing a long positive interval and short negative interval which brightens the

lamp to near full intensity. The duty cycle of the 200Hz square wave can be varied from approximately 5% to 95%. The two circuits below show how to connect the lamp to either the positive or negative side of the supply.





But the first circuit has a mistake and some components are not needed. The 555 will sink 300mA and it can be connected directly to the output transistor - you don't need the buffer transistor.
When the 555 goes HIGH, the voltage on Pin 3 is 1.5v lower than the 12v rail and thus the transistor does not turn off. The two diodes in the circuit below are needed to drop an additional 1v so the transistor turns off.



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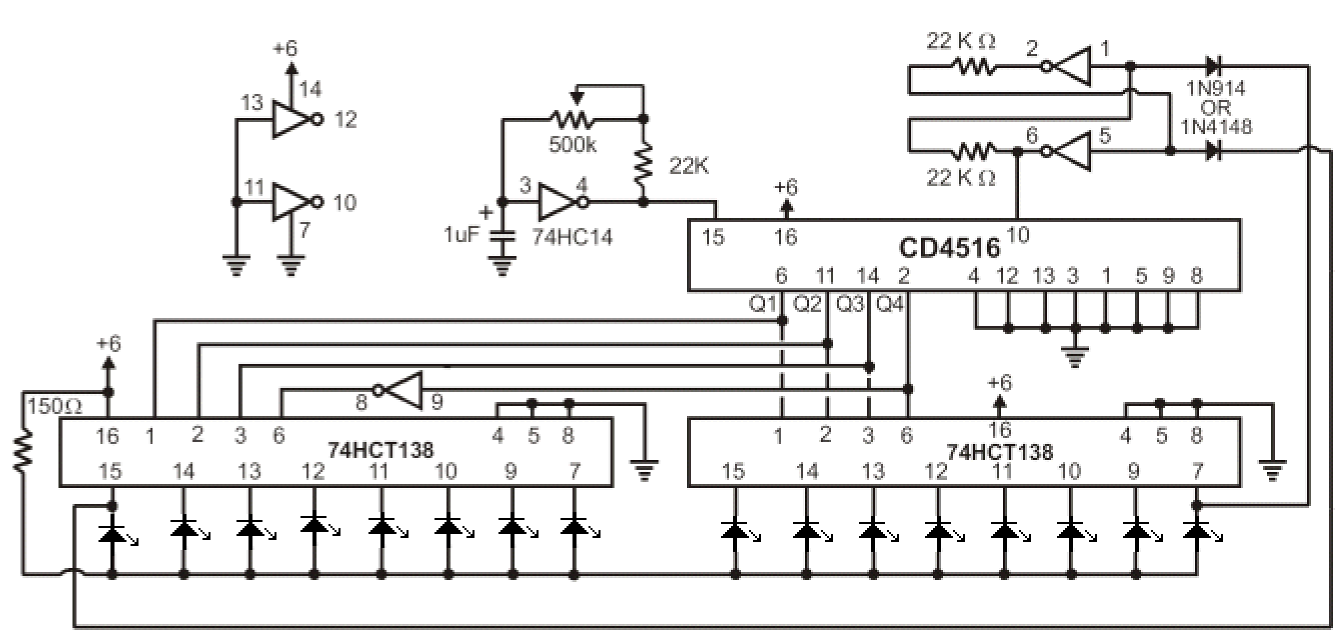
16-LED NIGHT RIDER



The bi-directional sequencer uses a 4 bit binary up/down counter (CD4516) and two "1 of 8 line decoders" (74HC138 or 74HCT138) to generate the popular Night Rider display. A Schmitt Trigger oscillator provides the clock signal for the counter and the rate can be adjusted with the 500k pot. Two additional Schmitt Trigger inverters are used as a SET/RESET latch to control the counting direction (up or down). Be sure to use the 74HC14 and not the 74HCT14, the 74HCT14 may not work due to the low TTL input trigger level. When the highest count is reached (1111) the low output at pin 7 sets the latch so that the UP/DOWN input to the counter goes low and causes the counter to begin decrementing. When the lowest count is reached (0000) the latch is reset (high) so that the counter will begin incrementing on the next rising clock edge. The three lowest counter bits (Q0, Q1, Q2) are connected to both decoders in parallel and the highest bit Q3 is used to select the appropriate decoder.

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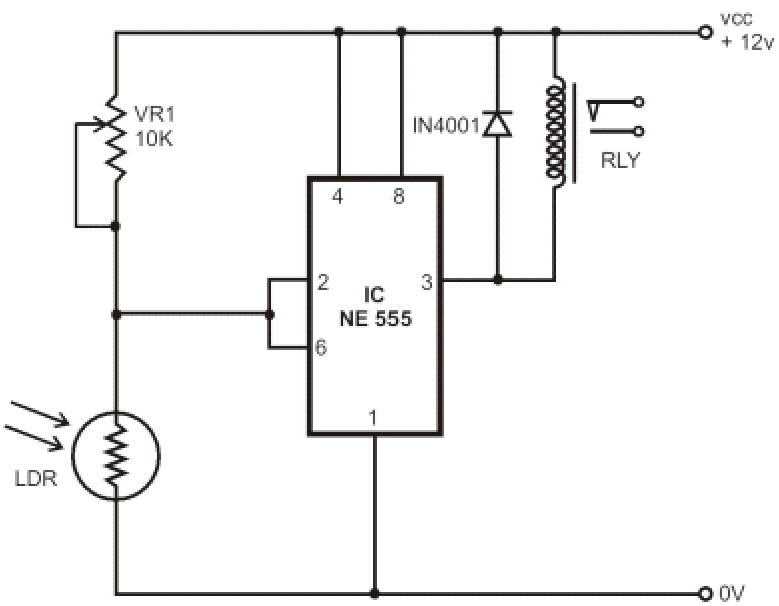
555 SCHMITT

The popular NE555 is used as a Schmitt trigger by connecting Pin 2 and threshold pin 6 inputs.
As the light falling on the LDR falls below a preset value the relay energises.

This happens when the voltage at pin 2,6 is greater than 2/3 of Vcc. When light increases, the voltage at pin 2,6 falls and at 1/3 of Vcc the relay is de-energised. This gives a Hysteresis range. Diode IN 4001 is necessary for the safety of the IC.



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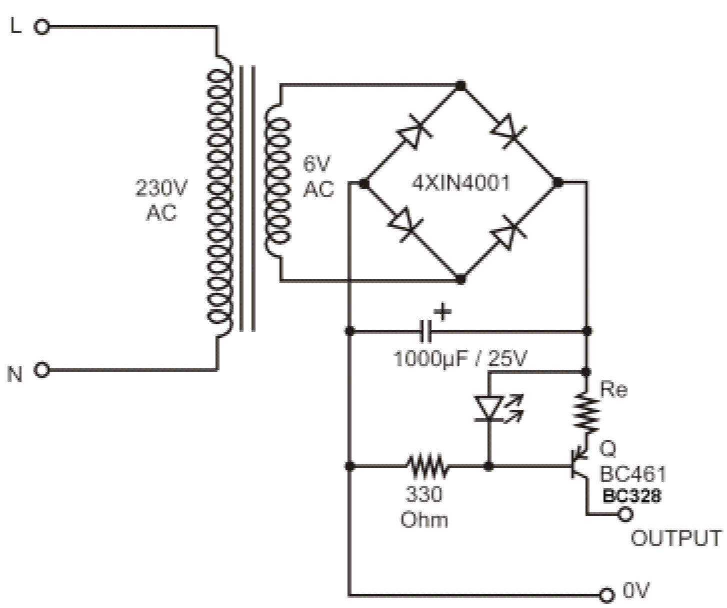
CONSTANT CURRENT SOURCE

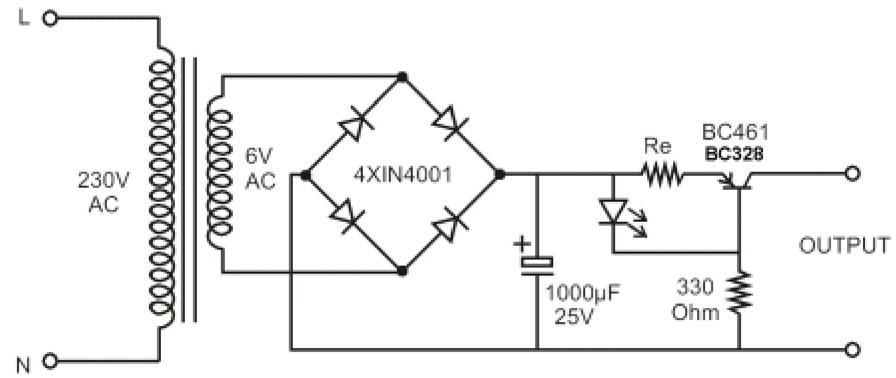
In the following circuit an LED is used to give a fixed reference voltage to a transistor. The output constant current I out is given by:

$$I_{out} = \frac{V_{LED} - V_{BE}}{Re}$$

The LED lights up only when a load is connected at the output. Thus it indicates when the circuit is operating.



The operation of the circuit can be made clearer by re-arranging the components as follows:



The output will be limited to 100mA by using a red LED and 10R for Re.
The output will be limited to 500mA by using a red LED and 2R2 for Re.
The output will be limited to 1A by using a red LED and 1R0 for Re.

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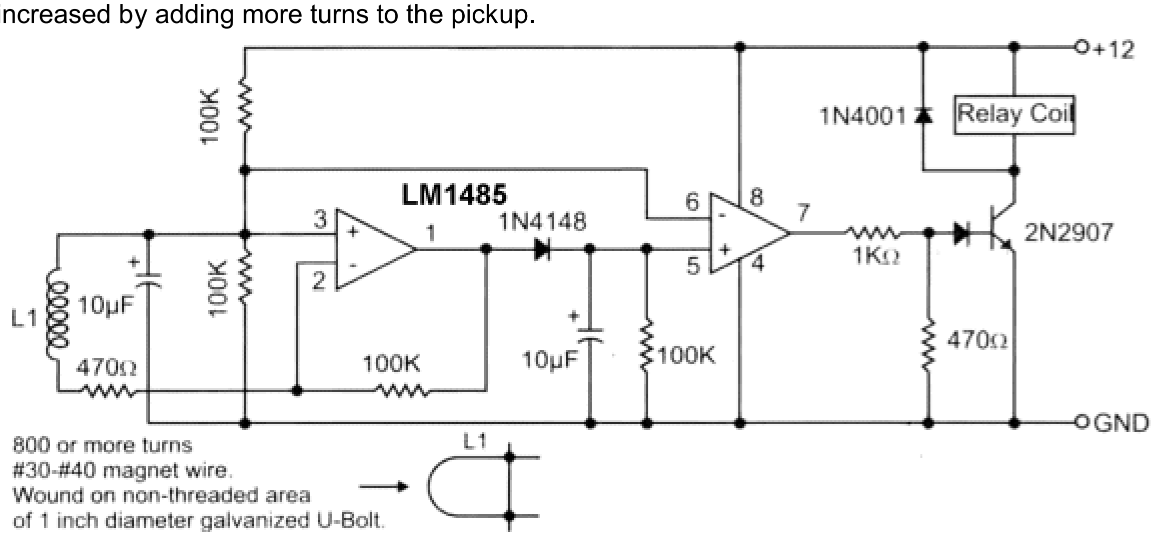
AC DETECTOR

This circuit will detect AC line currents of about 250mA or more without making any electrical connections to the line. Current is detected by passing on of the AC lines through an inductive pickup (L1) made with a 1 inch diameter U-bolt wound with 800 turns of #35 magnet wire. The pickup can be made from other iron type rings or transformer cores that allows enough space to pass one of the AC lines through the center. Only one of the current carrying lines, either the line or the neutral should be put through the center of the pickup to avoid the fields cancelling.
This is most important is very difficult to achieve. The best method is to make a short extension cord with the three conductors separated from each other.
If you make a 3-turn loop with say the active line, and pass a straight rod such as a metal bolt, containing 400 or more turns through the centre of the 3-turns, you will produce a very sensitive pick-up.
The magnetic pickup produces about 4 millivolts for AC line current of 250mA, or AC load of around 30 watts. The signal from the pickup is increased about 200 times at the output of the op-amp pin 7 which is then peak detected by the capacitor and diode connected to pin 7. The second op-amp is used as a comparator which detects a voltage rise greater than the diode drop. The minimum signal needed to cause the comparator stage output to switch positive is around 800mV which corresponds to about a 30 watt load on the AC line. The output of the 1458 op-amp will only swing within a couple volts of ground so a voltage divider (1k/470) is used to reduce the no signal voltage to about 0.7 volts. An additional diode is added in series with the transistor base to ensure it turns off when the op-amp voltage is 2 volts. You may get a little bit of relay chatter if the AC load is close to the switching point so a larger load of 50 watts or more is recommended. The sensitivity can be increased by adding more turns to the pickup.



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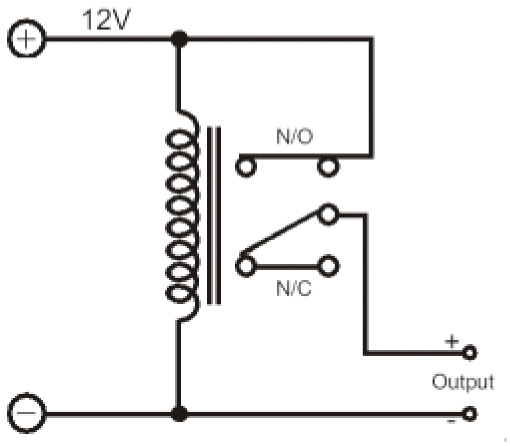
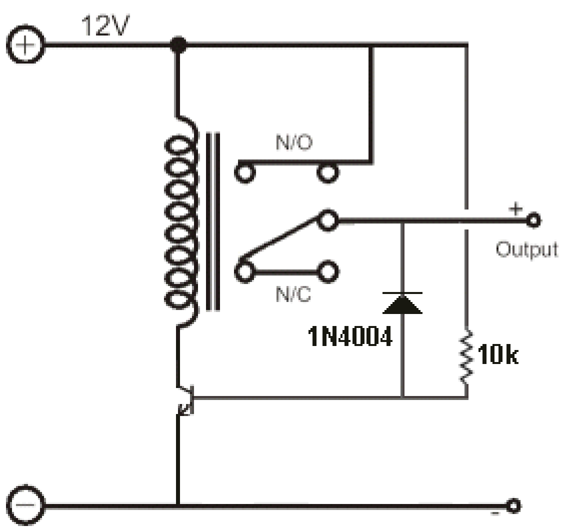
AUTO CUTOUT

A 12v relay is connected across the 12v supply. When the output is shorted, the 12v falls to 0v and the relay drops-out. The contacts open the 12v is

reapplied to the relay and it will "chatter" if the short is not removed.
This circuit will simply not work and the relay will simply become a "Buzzer."



In the following circuit, the transistor will only turn on if the output voltage is above 0.6v.



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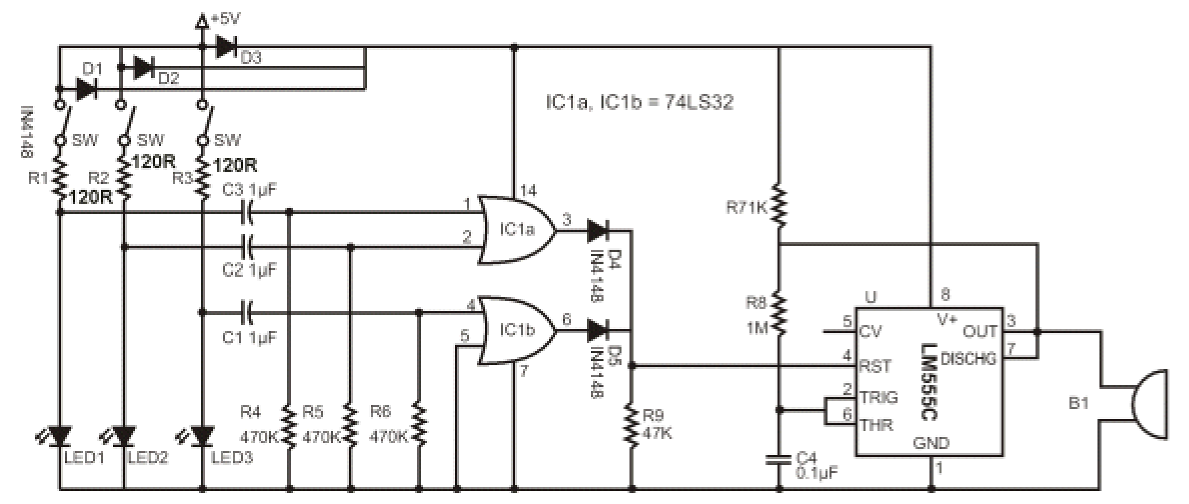
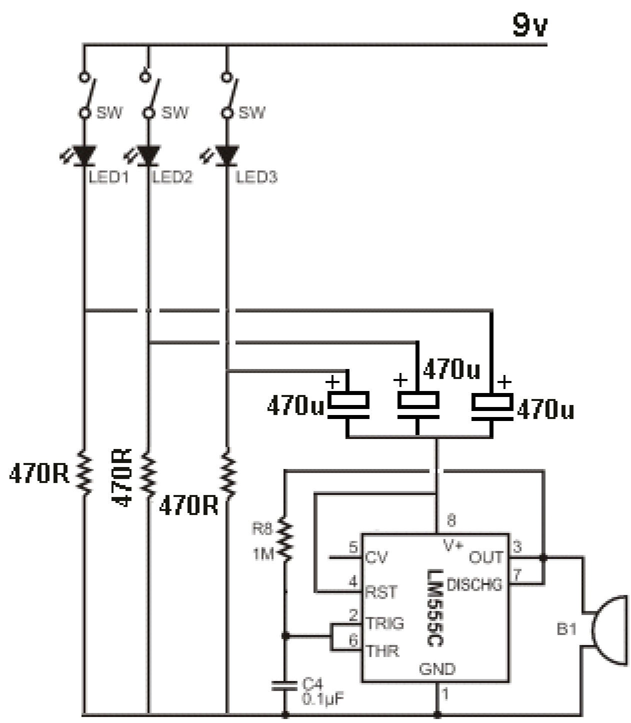
DOOR WATCHER

Three reed switches are at the heart of the circuit, one fitted to each door. They close when a door is opened. An associated LED lights when a door is opened.
The remainder of the circuit is powered by either D1, D2 or D3. However the 555 is not enabled until pin 4 goes high and this requires the output of either IC1a or IC1b to go high. In turn, this requires either pin 1 ,2 or 4 go high and this happens when a door opens. Because the high on each pin is only momentary (i.e. about 1/3 second, while C1 ,C2 or C3 is charging) there is only a short burst of buzzer activity (two brief beeps) at each door opening, after which it goes mute again.
So the beep calls attention to the fact that a door has opened and the LED indicates which door, staying lit until [i door is closed. If another door opens before the first door is closed, there is another beep and another LED lights.



The circuit above is too complex. It is very poorly designed. The 3 signals diodes are doing NOTHING. The are simply across each other!! One diode could be placed in the supply line to the 555 if it is needed for the reset line to work correctly. R7 is not needed as the output is taken to the pins 2&6 and the 74LS32 chip can be replaced by 3 x 470u electrolytics.
It can be simplified to this:



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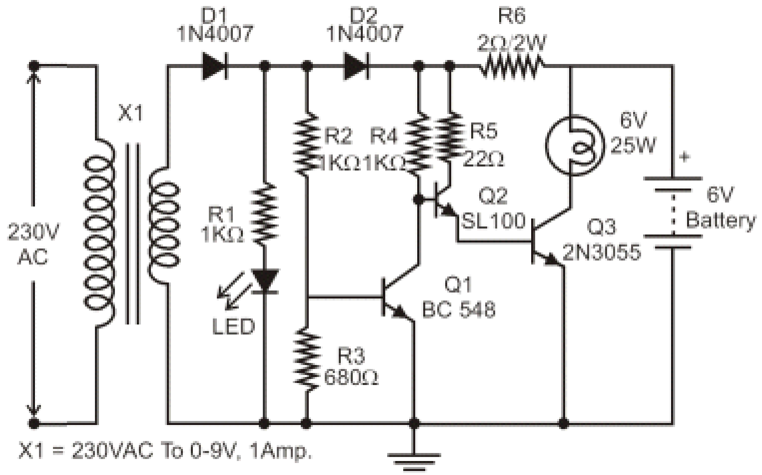
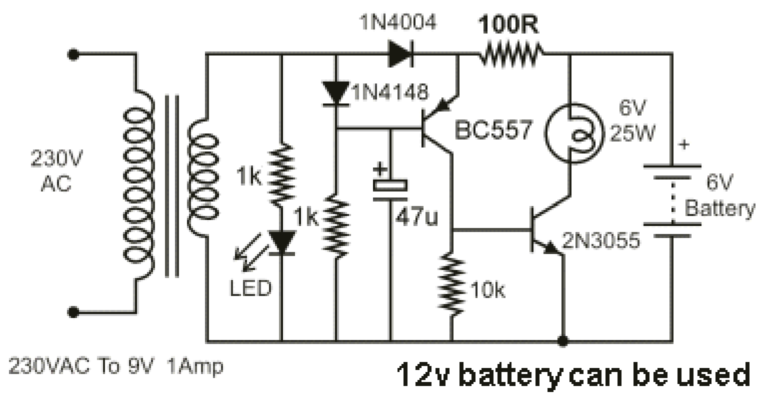
EMERGENCY LIGHT

Here is a circuit of an emergency light. As long as the power supply is present, transistor Q1 conducts. Since the base of the transistor Q2 is connected to the collector of Q1, transistor Q2 and Q3 do not conduct and hence the lamp remains off. LED glows as long as the supply is present.
When the power supply fails, the base drive to Q1 disappears. Thus Q1 stops conducting and its collector voltage jumps to battery voltage and starts conducting, switching on the lamp instantly. The load current is supplied by the battery. Whenever the power supply is restored, Q1 starts conducting turning Q2 & Q3 off and the lamp is switched off. Transistor Q2 conducts and provides sufficient base drive to transistor Q3.



The circuit above is too complex. The first diode is not needed and the rest of the circuit can be re-arranged. The 2R2 will overcharge the battery and dry it out in a few months.
It can be simplified to this:



The 100R gives 40mA charging with a 12v battery and 12v DC plug pack.

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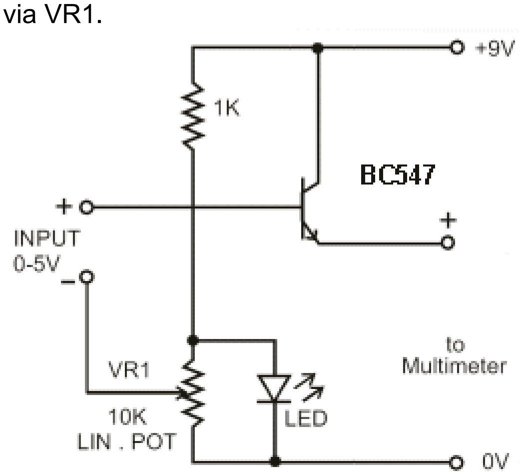
INCREASING THE INPUT IMPEDANCE

The input impedance of a low cost analogue multimeter can be improved using this circuit. The approximate impedance increase will be about 250. The LED provides a fixed reference voltage for zero setting of the multimeter via VR1.



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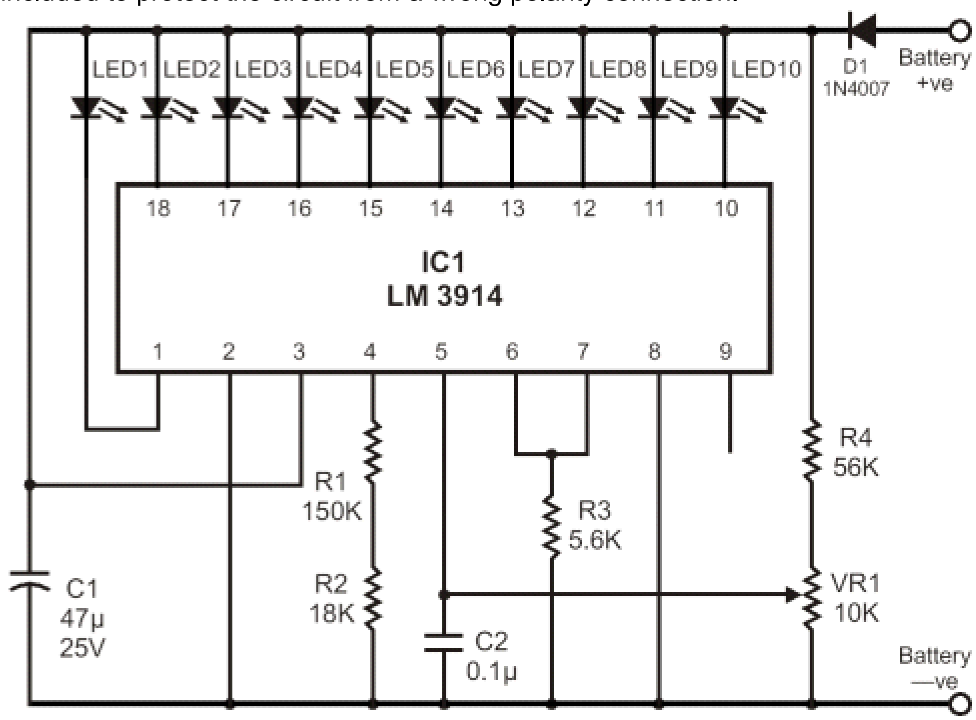
BATTERY MONITOR

This circuit makes it possible to monitor the charging process of a battery. After constructing the circuit, final adjustments are simple and the only thing needed is a digital voltmeter for the necessary accuracy. Connect an input voltage of 12.65 volt

between the positive and negative connections of the circuit and adjust the VR1 (10K trimmer) until Led 10 lights up. Lower the voltage and in sequence all other LEDs will light up. Check that Led 1 lights up at approximately 11.85 volts. At 12.65 volt and higher the battery is fully charged, and at 11.85 is considered to be at its lowest state. LED 8, 9 and 10 indicate the battery capacity is more than 50%, LED 4 to LED 7 indicate a capacity of 30% - 50% and LED 1 to LED 3 indicate less that 30%. This circuit, with the components shown, uses less than 10mA. Of course you can adapt it to your own needs by making small modifications. This circuit is set for DOT mode, meaning only one LED at a time will be lit. If you wish to use the BAR mode, connect pin 9 to the positive supply rail, but obviously with increased current consumption. The LED brightness can be adjusted by choosing a different value for the 5k6 resistor connected at pin 6 and 7. The diode 1N4007 was included to protect the circuit from a wrong polarity connection.



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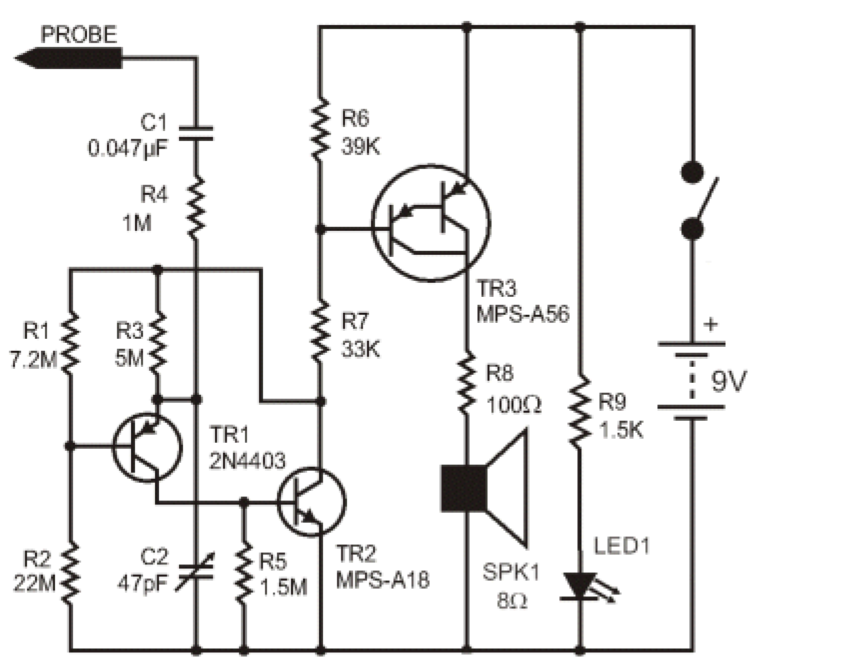
CAPACITANCE BEEPER

Here is a circuit of capacitance beeper which uses a two-transistor flasher in conjunction with a Darlington transistor. When the probe is touched to a capacitor, the project beeps at a frequency that varies with capacitance. The frequency change is so noticeable that small capacitors can be precisely matched or an exact fixed value can be selected to replace a trimmer in a prototype.
When the beeper is properly adjusted it draws only 10uA with nothing touching the probe excluding the LED current. This design is optimized for capacitors less than about 100n. Large capacitors give a low frequency clicking sound and small capacitors sound a tone that increases as the capacitance decreases. Many decades of frequency change occur over the beepers range.
The probe should be built into a metal box so that one hand makes good contact to 0v.
The resistor values are selected to barely turn on the transistors to conserve battery power. The transistors must have very high gain and good low current properties. The MPS-A18 is a very high gain transistor with excellent gain at very low currents. The capacitors are not particularly critical but the trimmer might require a little care. The trimmer is adjusted until the beeping just stops and only a very weak squeal is heard when a 2.2p is touched to the probe.



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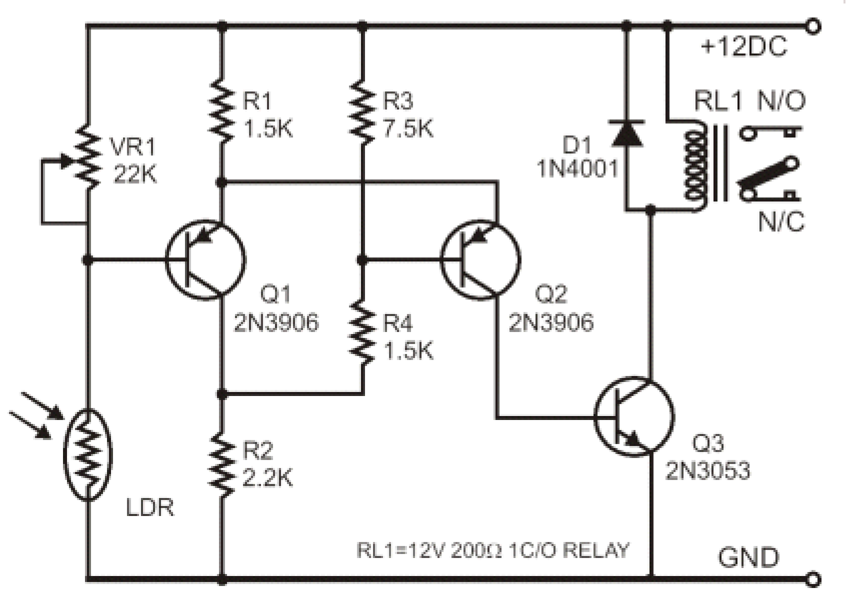
LIGHT CONTROLLED LAMP

Here is a circuit of light controlled lamp. This is basically a Schmitt Trigger which receives input from a cadmium sulfide photo cell and controls a relay that can be used to switch a lamp on and off at dawn and dusk. The photo cell should be shielded from the lamp to prevent feedback so the lamp light does not strike the photo cell and switch off the lamp.
The photo cell is wired in series with a potentiometer VR1, so the voltage at the base of transistor Q1 can be adjusted to about half the supply, at the desired ambient light level. The two PNP transistors are connected with a common emitter resistor to produce a gap between the on and off voltages - called the HYSTERESIS GAP.
Under dark conditions, the photo cell resistance will be high producing a voltage on the base of Q1 that is higher than the base voltage on Q2. This causes Q2 to conduct and activate the relay.
The switching points are about 8 volts and 4 volts using the resistor values shown but could be brought closer together by using a lower value for R3. A value of 3k3 would move the levels to about 3.5v and 5.5v.



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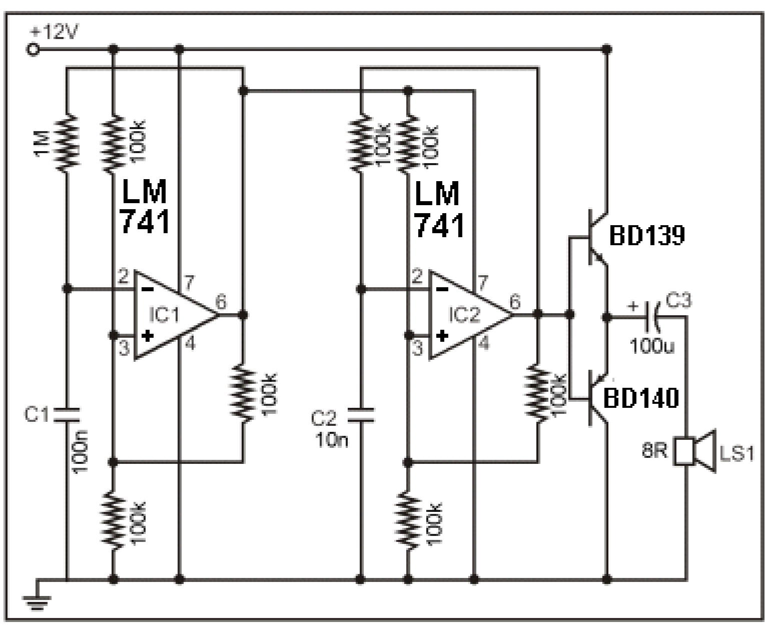
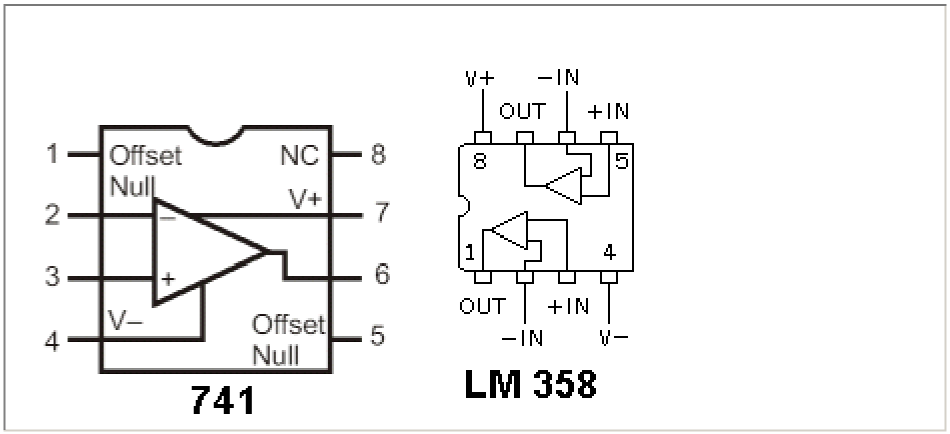
ELECTRONIC SIREN

The 741 is a versatile chip and it can be used in the design of a wide variety of sound-effect generators. This circuit produces a siren that can be used in conjunction with other circuits. You can also use an LM358 dual op-amp chip.
The operation of the op-amp was not discussed correctly in the original article, so a full explanation has been provided:
The principle of an op-amp is to provide a very high gain. This means a small change in either input produces an almost full rail swing on the output.
The circuit starts to work like this.
As soon as you put a slight voltage on the "+" input, the output goes full HIGH.
The two 100k resistors on the "+" makes the output go full HIGH.
Now we connect a resistor from the output to "+" and this makes no difference. The output remains full HIGH.
Now we put a resistor from output to "-."
If the "-" input is slightly higher than "+" the output goes LOW. This is what happens. The output voltage drops until the "-" input is slightly lower than the "+" input and that's why the output falls until its voltage is equal to the "+" input.
Now we connect a capacitor to the "-" input.
It does not matter if we add the capacitor later or turn the circuit on with the capacitor fitted.
The voltage on the "-" input will be lower than the "+" input and this will start the circuit oscillating.
This is how it oscillates:
Because the "-" input is lower than the "+" input, the output rises towards the positive rail and this begins to charge the capacitor.
The voltage on the "-" input can rise higher than the "+" input and when it is about 15mV higher, the output drops towards the 0v rail.
This reduces the voltage on the "+"input and the capacitor has to discharge a considerable amount before it is lower than the "+" rail. (Actually before the "+" input is higher than the "-" input).
The voltage on the "+" input is rising and falling by about 30% of rail voltage and this is the amount the capacitor has to charge and discharge for the circuit to work.



Circuit diagram of the Electronic Siren



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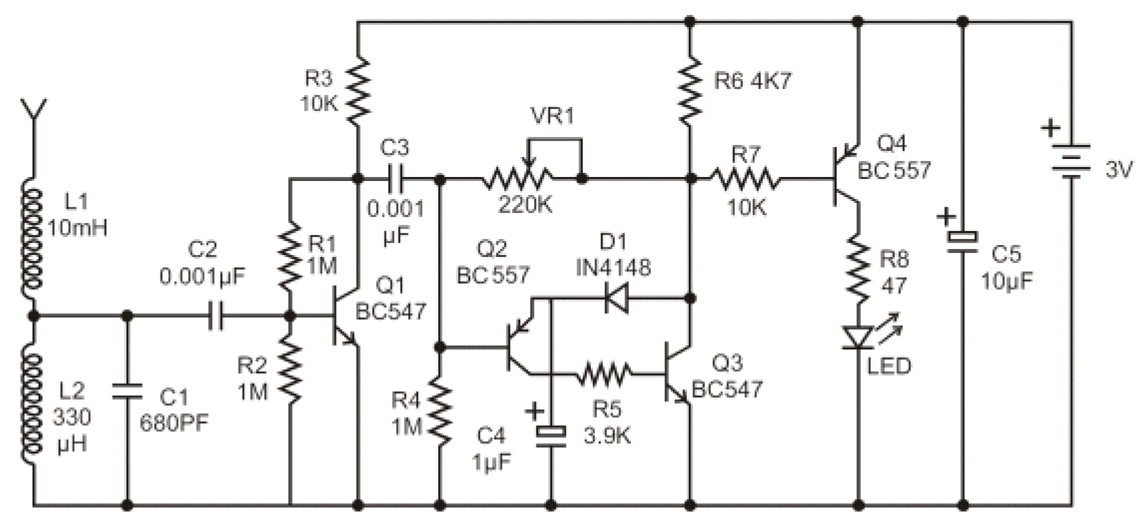
LIGHTENING DETECTOR

Clouds can carry such huge electric charges that may to cause lightning flashes of thousands of volts. It is really a fascinating phenomenon.
When a lightning flash takes place a broad spectrum of radio-frequencies is generated. In this broad spectrum there is special intense emissions of the VLF (Very Low Frequency) band. This project will allow you to build a receiver to pick up a band near 300 KHz. An LED will flash to indicate the lightning flashes.

THE CIRCUIT

The radio-signal generated by the lightning flash is picked up by the telescopic antenna with the help of a 10mH choke. The choke L1 resonates with the antenna and allows current to flow into the receiver circuit.
The L2 of 330uH in parallel with the 680pF capacitor C1 forms a tuned circuit for 300KHz. This parallel-tuned tank circuit is coupled to the base of Q1 via D2. The amplified radio signal is again coupled into the base of Q2. Transistors Q2 and Q3 form an LED flasher circuit. Transistor Q4 is the LED driver.
The flasher is biased so that when VR1 is carefully adjusted the LED flashes only when a radio burst appears at the input due to a lightning flash.
Positive feedback ensures the LED to be full on. The circuit quickly resets by charging C4 capacitor through diode D1.
The circuit draws only about 100uA in idle state. Therefore it can run on two cells for many hours.



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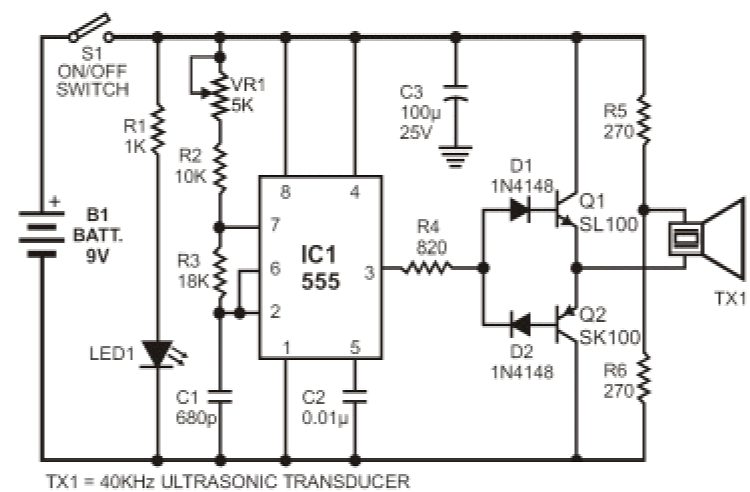
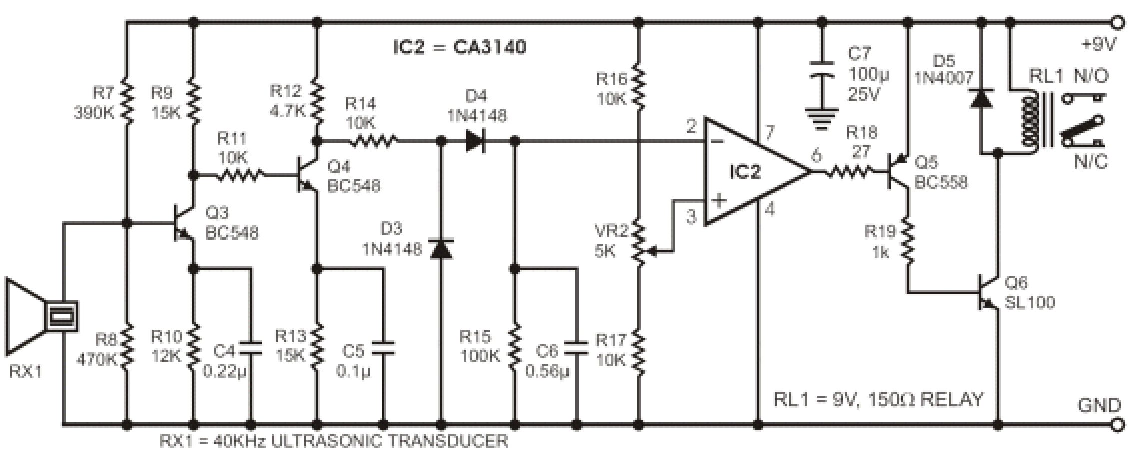
ULTRASONIC REMOTE CONTROL

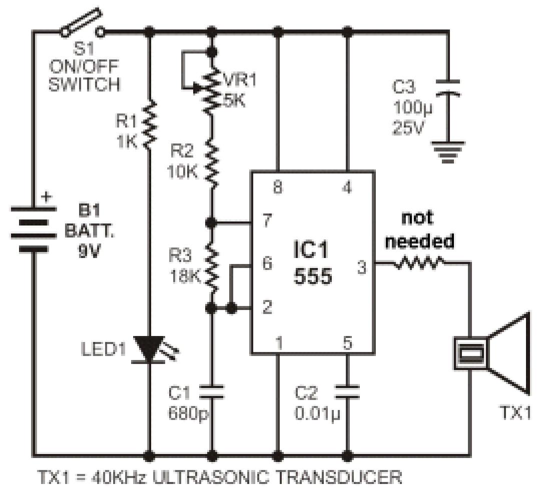
Here is a low cost, wireless switch controller. It uses ultrasonic sound waves for remote control of a switch.
As with any other remote control, the system basically comprises a transmitter and a receiver circuit. Frequencies up to 20kHz are audible. Frequencies above 20kHz are not audible. The transmitter circuit generates an ultrasonic frequency between 40-50kHz. The receiver senses the ultrasonic sound and switches on a relay.

The transmitter uses a 555 astable multivibrator. It oscillates at a frequency of 40-50kHz. An ultrasonic transducer is used to transmit the frequency. The transmitter runs on a 9v battery. The ultrasonic receiver uses a receiver transducer to sense ultrasonic signals. It uses a two-stage amplifier, a rectifier stage and an operational amplifier in inverting mode. Output of the operational amplifier is connected to a relay through a driver stage. A 9v adapter can be used to power the receiver circuit. When switch S1 is pressed, it generates ultrasonic sound. The receiver amplifies the received signal via transistors Q3 and Q4. The amplified signal are then rectified and filtered. The filtered DC voltage is given to the inverting pin of operational amplifier 1C2. The non-inverting pin of 1C2 is connected to a DC voltage through VR2 that determines the threshold value of the signal received, for operation of relay RL1. The inverted output of 1C2 is used to bias transistor Q5. When transistor Q5 conducts, it supplies base bias to transistor Q6. When transistor Q6 conducts, it energises the relay RL1 . The relay can be used to control any electrical or electronic appliance.
Frequency of the circuit can be varied by adjusting VR1. Adjust it for maximum performance. Ultrasonic sounds are highly directional. So when you are using the transmitter, the receiver should face towards the transmitter. The receiver is always kept on.





The transmitter circuit can be simplified to the following design as the driver transistors are not needed. They do nothing.



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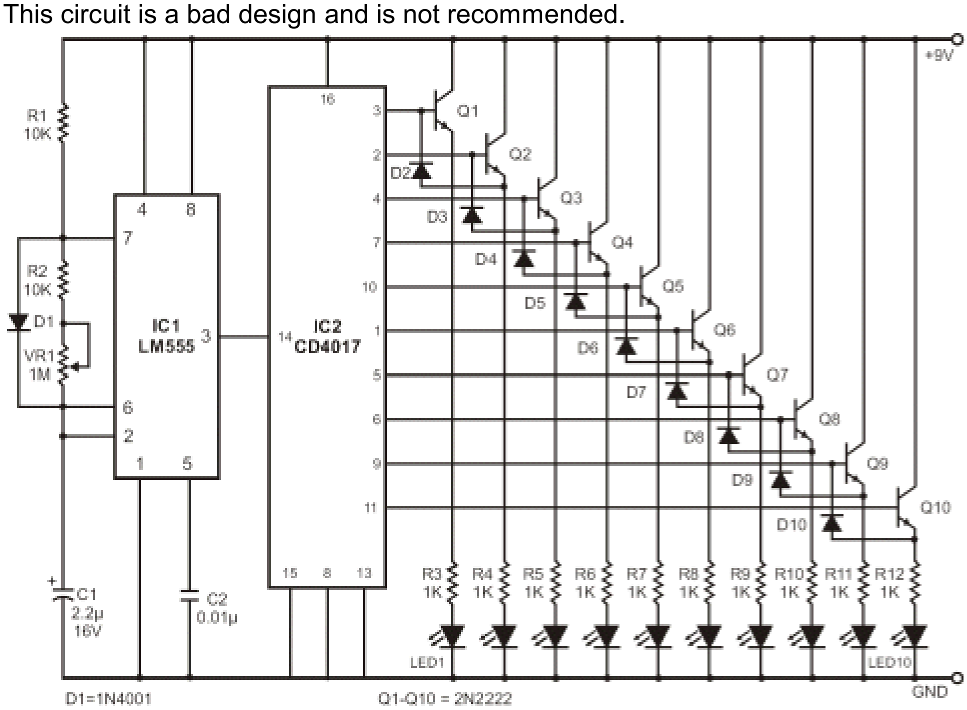
MOVING LEDs

Here is another disastrous circuit. As each output goes high it pulls the previous output high to turn on two, three, four LEDs etc.
But any output that is not high is PULLED LOW by the chip and this circuit is pulling the outputs HIGH against the drivers inside the chip. This could lead to failure and certainly will heat up the chip.
This circuit is a bad design and is not recommended.



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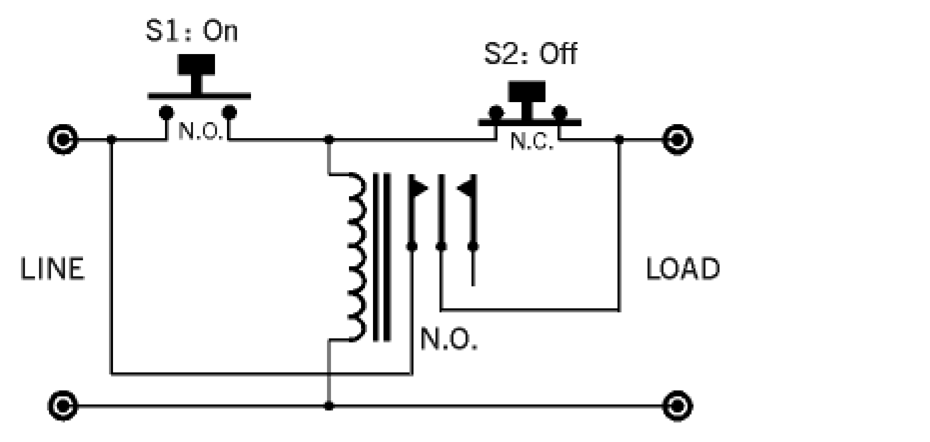
ON-OFF SWITCH

Here's how industrial equipment is started and stopped using momentary pushbuttons. The circuit is called a "locked-out relay."
It uses an ordinary relay and the ON switch activates the relay to close the terminals. When the switch is released, the relay remains activated and the load is powered via the contacts of the relay.
When the OFF switch is pressed, the relay is de-energised and the contacts open. This removes power to the load.



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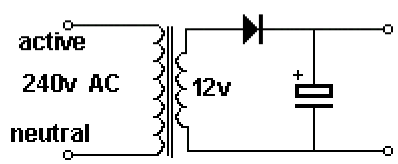
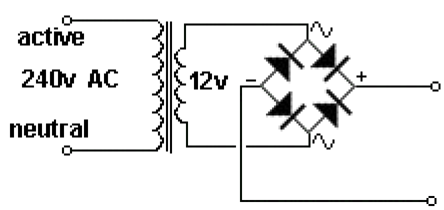
6v and 12v FROM TRANSFORMER

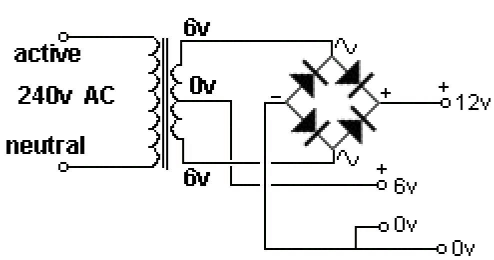
It is not a good idea to connect a single diode to the output of a transformer to produce a power supply as this will only take one-half of the energy from the winding (transformer) and the other half of the cycle will create magnetic flux in the core of the transformer that is not removed. When the next cycle is delivered to the transformer the core is already nearly saturated and it will become over-saturated and the transformer will heat up. You need to use a bridge rectifier. Here are 3 circuits. Note the clever design using a centre-tapped 6v - 0v - 6v transformer to produce two outputs. If a transformer is rated at 1A, this is an AC rating and must be de-rated to 707mA for your power supply. This means you only have a total 700mA for the 5v and 12v lines COMBINED.



Do NOT use a single diode



Use a BRIDGE RECTIFIER



A 6v - 0v - 6v centre-tapped transformer provides two output voltages

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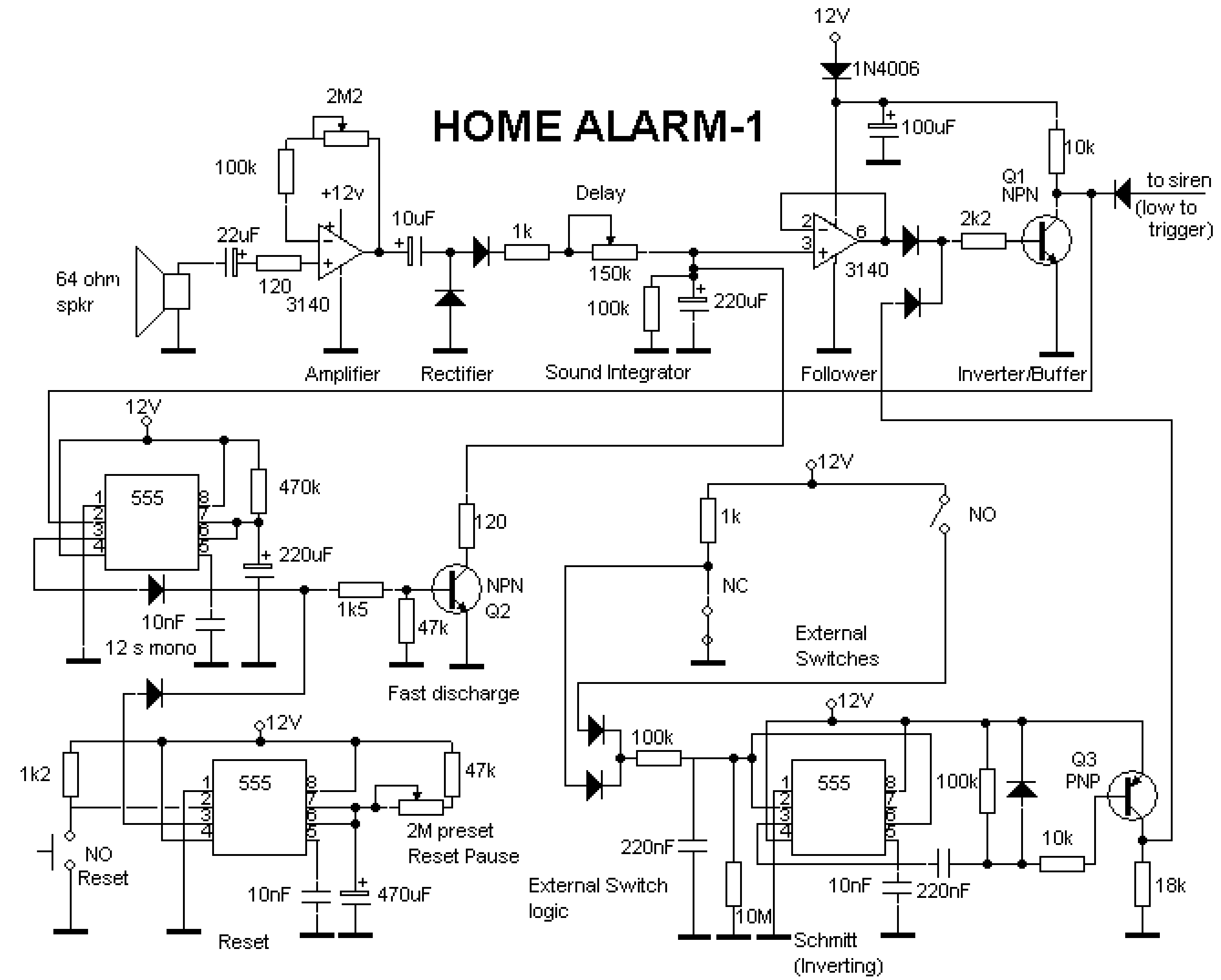
HOME ALARM-1

Here is a **Home Alarm** using 555 IC's.



The Home Alarm-1 circuit above can be simplified by using a single 74C14 IC. This IC is also known by the following numbers: 40106, 40014, and 74HC14. These are CMOS chips and are characterised by low current consumption, high input impedance and a supply voltage from 5v to 15v. **(Do not substitute 7414 or 74LS14. They are TTL chips and operate on 4.5v to 5.5v and have low impedance inputs.)**

The 74C14 contains 6 Schmitt Trigger gates and 4 of these gates (Schmitt Inverters) are used in this circuit.

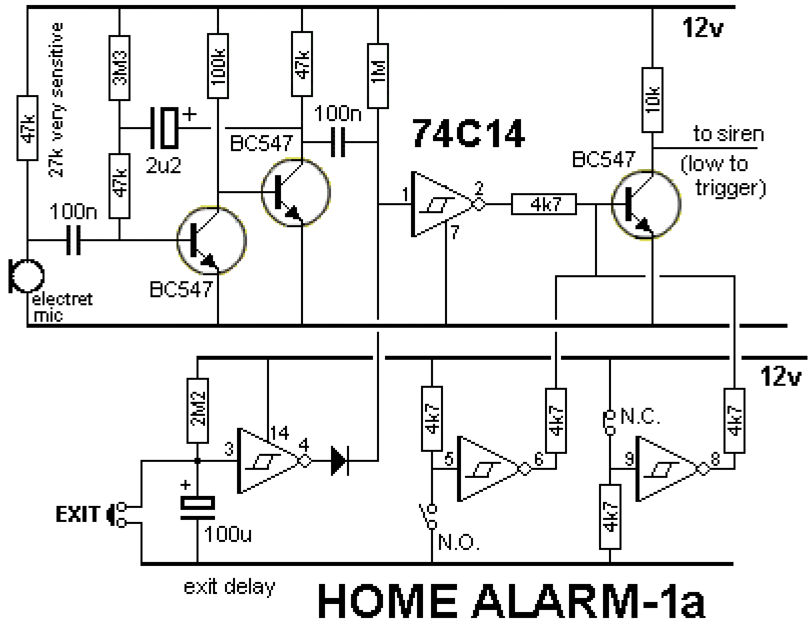
The circuit consists of a number of "building blocks" and the first consists of two transistors in a very clever "bootstrap" arrangement. The first transistor is turned on via the 3M3 and 47k. The second transistor is not turned on and the output is HIGH.

A small signal from the electret microphone will consist of positive and negative excursions and the negative excursion will turn the first transistor OFF. This will turn the second transistor ON and the left lead of the 100n will be pulled towards the 0v rail. The 100n is uncharged and the right lead will also be pulled towards the 0v rail and the input of the 74C14 will see a LOW. This will make the output HIGH and turn on the BC547 transistor.

When the second transistor turns ON, it also pulls the 2u2 down and this removes the "turn-on" voltage to the first transistor. The two transistors remain in this state for a few seconds while the 2u2 discharges and the voltage on the base of the first transistor rises. When this happens, the two transistors change state and the 2u2 charges.

When the circuit is waiting to detect audio, the 2u2 is charged via the 47k on the base of the first transistor and 47k collector resistor of the second transistor (plus the base-emitter voltage drop of the first transistor).

To exit the property, the **EXIT** button is pressed and this puts a HIGH on pin 1 of the IC so that any signal from the electret mic is not passed to the siren. The EXIT delay is determined by the value of the 100u and 2M2. Normally-open and normally-closed switches will also send a LOW to trigger the siren.



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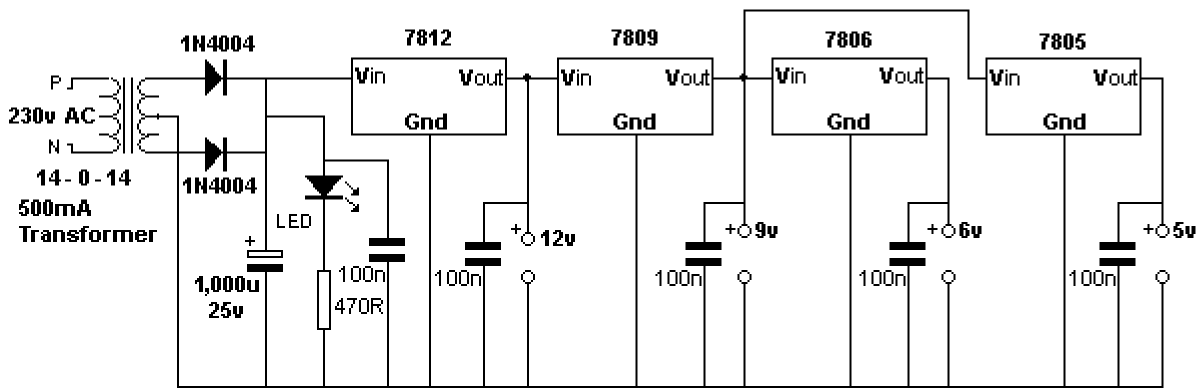
BENCH POWER SUPPLY

Here is a regulated power supply for you bench. The 100n capacitors are needed across the input and output of the regulator IC's to prevent high-frequency instability.



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EM

Here is a
The circuit

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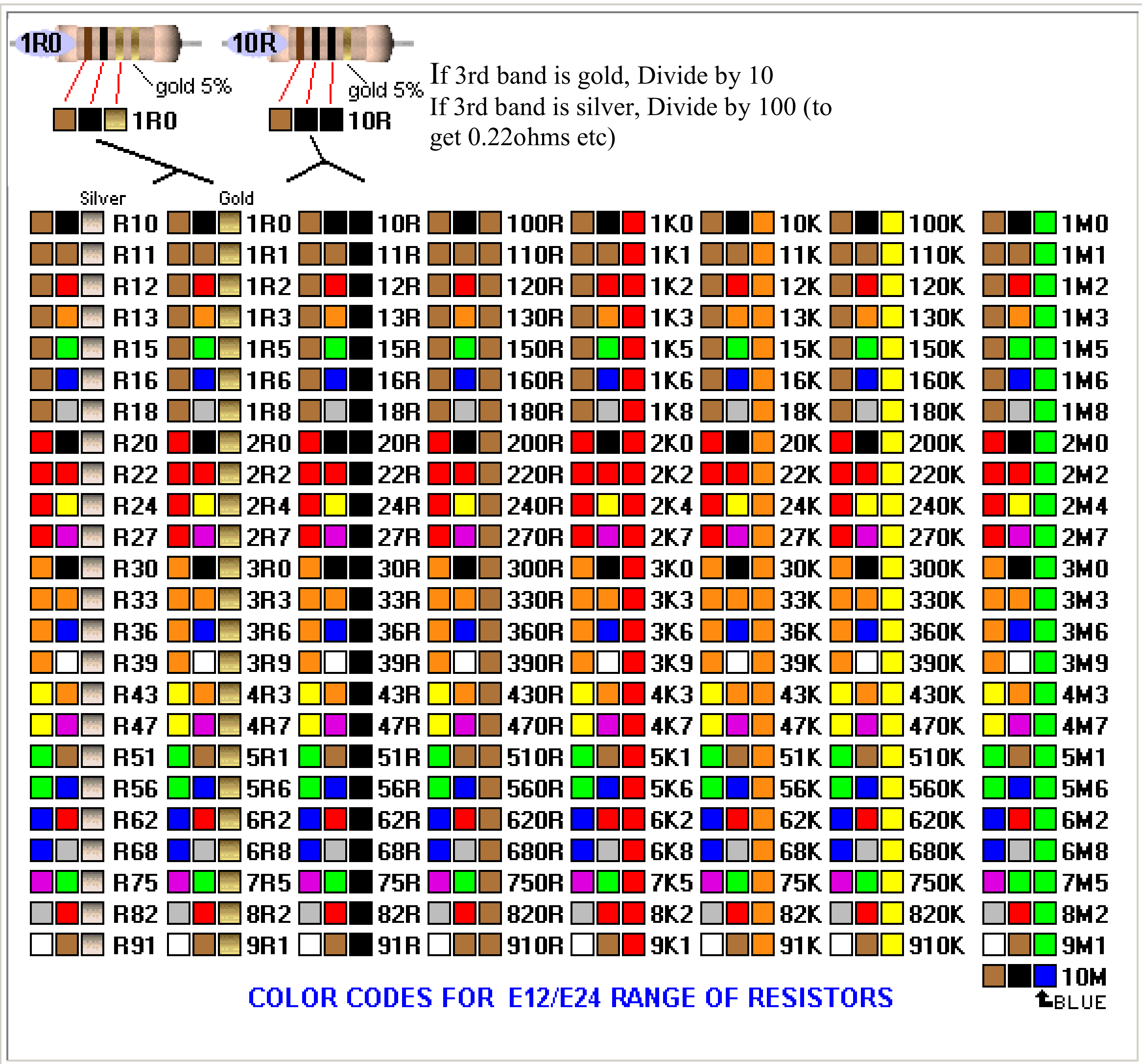
EM

Here is a
The circuit

RESISTOR COLOUR CODE

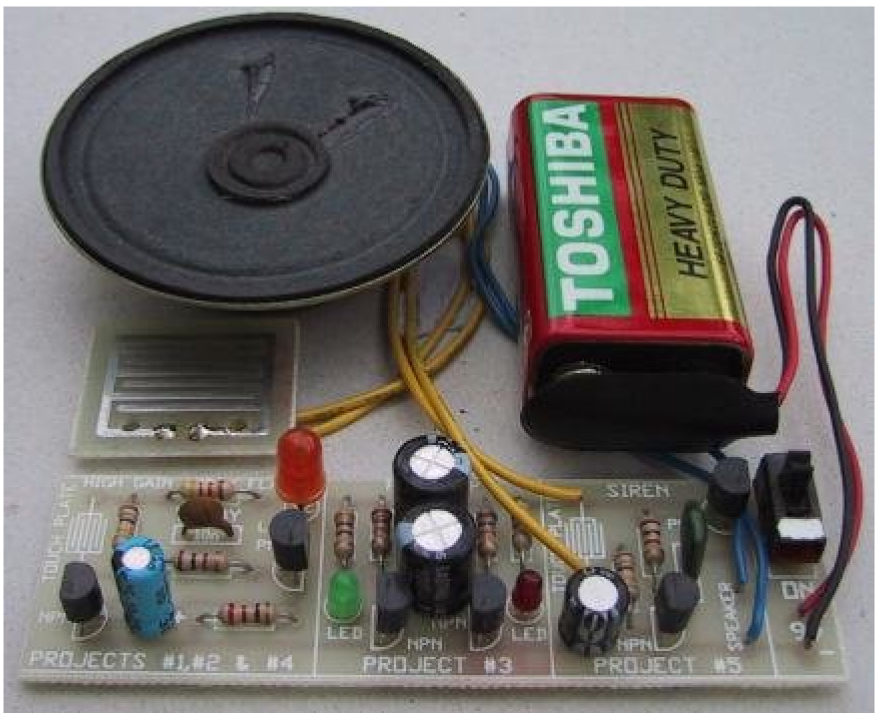
The first three colour bands of every resistor can be found in the following chart:



5 PROJECTS TO BUILD

By Colin Mitchell

Learn BASIC ELECTRONICS while building 5 simple projects



The complete 5-Projects

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An educational course requiring soldering skills to construct electronic projects

THE 5 PROJECTS:
1. A two-transistor high gain amplifier
2. A LED flashing circuit
3. A Flip Flop circuit to alternately flash two LEDs
4. A Fibre Optic project to create a miniature sign
5. A Simple Siren Project using a touch plate to raise and lower the tone

INTRODUCTION

This course has been prepared for **TALKING ELECTRONICS** **Interactive** by Colin Mitchell of **Talking Electronics**, to teach beginners the practical side of electronics.

Talking Electronics has been in the field of educational electronics for many years and they have a wide range of electronics kits, both analogue and digital for the hobbyist and experimenter and specialise in teaching **HOW A CIRCUIT WORKS** and how to get it going, if it doesn't work.

The projects in **5-Projects** are an ideal place to start. They are simple and teach soldering, assembly, testing and experimenting. They are all built on a long printed circuit board that is divided into sections. Each project is identified on the board by a white border and a project number.

Complete construction details are included for each project in this "e-book" as well as theory and notes on resistors, capacitors, transistors, the Light Emitting Diode (LED) and a number of other essential electronic components.

Just about everything you need to know is included to get the projects working. Each project includes a section on **HOW THE CIRCUIT WORKS** and getting it to work, (if you have difficulties). All this information provides you with an ideal grounding in basic electronics.

A list of components for the 5 projects is shown on page 6 and the only other things you will need are: a small soldering iron, some fine solder and side cutters.

This e-book is designed to get you started in the real world of soldering and assembly on a printed circuit board.

If you have not done any soldering before, you should get someone to show you how it is done as it is very important to get the actions and timing right to make a nice clean, shiny connection without damaging the components.

We have included a page on soldering to assists you but it is always best to get someone to show you first hand.

THE BUILDING BLOCK APPROACH

These pages use the **building block** approach to teach electronics. Simple electronic circuits are called building blocks and once you know how they work, you will be able to combine two or more to create larger circuits.

The building blocks we are covering are:
1. The NPN/PNP high gain amplifier,
2. The multivibrator (flip flop) and
3: The oscillator.

SUMMARY OF THE PROJECTS

PROJECT 1:

THE HIGH GAIN AMPLIFIER

This project shows how two transistors can be used to turn ON a Light Emitting Diode (LED) from a touch plate. The amplifier has a gain of more than 10,000. It is our **High Gain Amplifier** building block.

PROJECT 2:

THE LED FLASHER

A two transistor circuit is used to flash a Light Emitting Diode
- The touch plate is used to change the flash rate.
- A fixed resistor is used to set the flash rate to 2Hz (2 flashes per second).

PROJECT 3:

THE FLIP FLOP

A Flip-Flop circuit is constructed on the Printed Circuit board to alternately flash two Light Emitting Diodes (LEDs). This is our **Flip Flop** building block.

PROJECT 4:

FIBRE OPTICS

Create your own flashing fibre optic sign using the LED Flasher circuit and a 7x10 (holes) matrix board to produce a wide variety of signs and shapes using the plastic optical-fibre included.

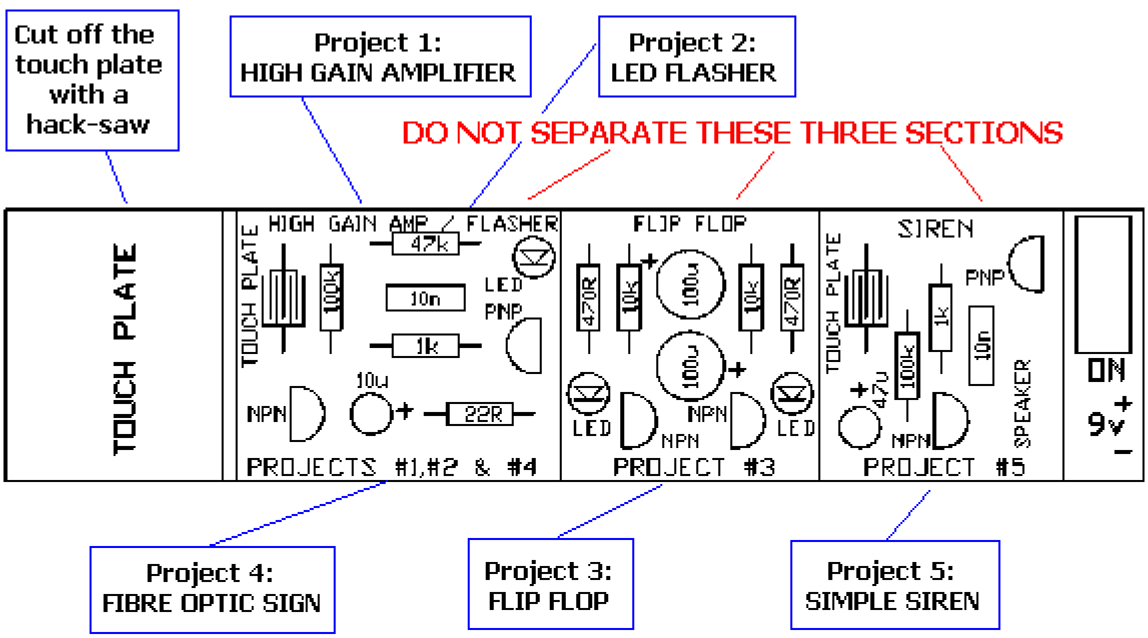
PROJECT 5:

SIMPLE SIREN

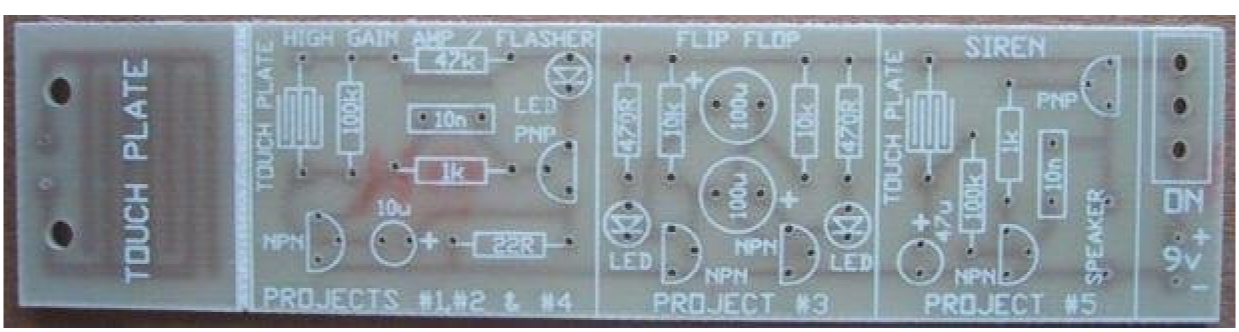
A **Simple Siren** circuit is constructed on the Printed circuit board and the touch plate is used to raise and lower the tone. This is our oscillator building block.
This project can be used to detect water (such as rain) on the touch plate or water level such as in a bath or tank or the flooding of a cellar.

THE PRINTED CIRCUIT BOARD

The **TOUCH PLATE** is cut off the Printed Circuit Board leaving 3 areas for the 5 projects as shown below:
The **HIGH GAIN AMPLIFIER** is built on the first section, then two more parts are added to make the **LED Flasher** on this section. The **FLIP FLOP** is built on the second section. The **Fibre Optic Display** uses the circuit from the first section and the 7x10 matrix board included in the kit. The fifth project **SIMPLE SIREN**, is built on the third section of the board.

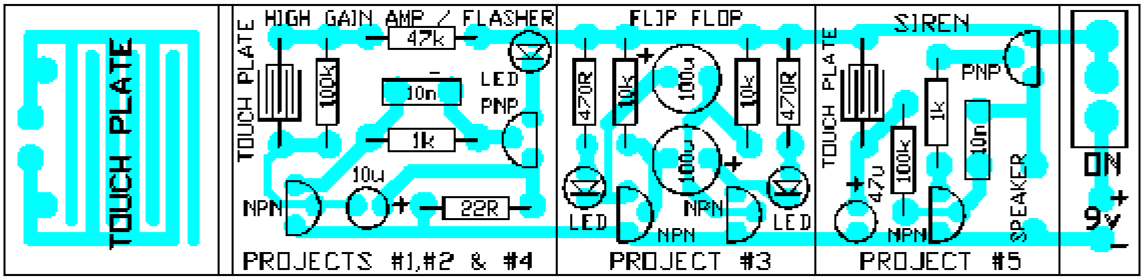


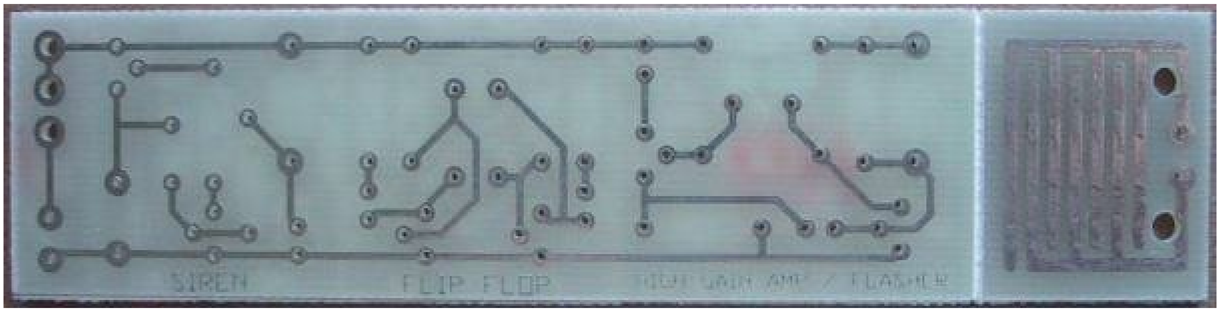
THE PC BOARD FOR THE PROJECTS IN THIS COURSE



The complete PC board showing the "break-off" Touch Plate

View of the Printed Circuit Board showing the copper tracks under the board:





The underside of the board showing the Touch Plate grid

PARTS LIST

See each experiment for individual parts list. More identification of each component can be found in the pages that follow.

RESISTORS - all 1/4 watt, 5%   [Resistor Colour Code Calculator]

1 - 22R (22 ohms)   colour bands: red-red-black-gold
2 - 470R (470ohms)   colour bands: yellow-purple-brown-gold
2 - 1k (1,000ohms)   colour bands: brown-black-red-gold
2 - 10k (10,000ohms)   colour bands: brown-black-orange-gold
1 - 47k (47,000ohms)   colour bands: yellow-purple-orange-gold
2 - 100k (100,000ohms)   colour bands: brown-black-yellow-gold

CAPACITORS

2 - 10n (103) (10 nanofarads) 50v ceramics

ELECTROLYTICS

1 - 10u (10 microfarad)16v single-ended electrolytic
1 - 47u (47 microfarad) 16v single-ended electrolytic
2 - 100u (100 microfarad) 16v single-ended electrolytics

TRANSISTORS

4 - BC 547, 2N 2222, 2N 3904, 9013 or equivalent transistors
2 - BC 557, 2N 2907, 2N 3906, 9015 or equivalent transistors

LIGHT EMITTING DIODES etc:

1 - 3mm red LED for project 3
1 - 3mm green for project 3
1 - 5mm super-bright LED for projects 1, 2 and 4.
1 - 8R speaker (8 ohm mini speaker)
1 - on/off SPDT switch (slide switch - single pole double throw)
1 - 9v battery snap
1 - 9v battery
1 - 40cm hook-up wire for Touch Plate and speaker
1 - 3m (10ft) plastic fibre optic cable
1 - PC board for fibre optic sign with 10x7 matrix of holes
1 - drinking straw to place over LED
1 - 5-PROJECTS PC board

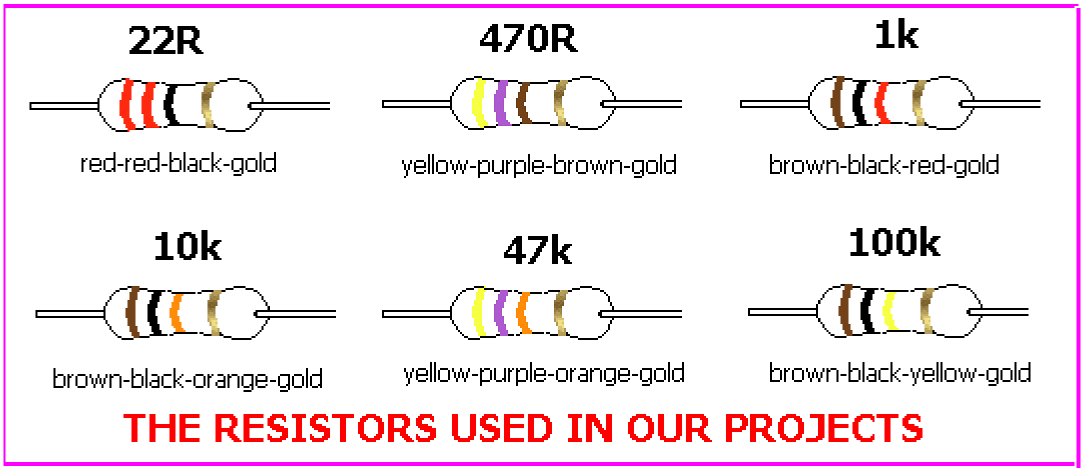
THE RESISTOR

The resistors used in these projects are identified by coloured bands. These bands are painted around the body to identify its value. TALKING ELECTRONICS **Interactive** has a calculator that delivers the value of resistance, when you enter the colour bands. This calculator can be found "HERE."

Nearly ALL the resistors used in our projects have a gold band. This indicates the resistor can be 5% larger or smaller in value than the indicated value. Most resistors are **very close** to the indicated value and, in general, the value of a resistor is not important.

We will now explain how to work out resistance values by using the colour bands. Hold the resistor so the fourth band is GOLD.

The first two bands of colour provide the two digits in the answer and the third band provides the number of zeros. The answer will be in OHMS.
The letter "R" means "Ohms". The letter "k" means "thousands of ohms" or kilo-ohms.
Here are the resistors used in the projects and their colour bands:



In a moment we will show how the colours are worked out but first we will discuss resistors in general.

PREFERRED VALUES

The value of a resistor is measured in ohms. A low value resistor may be 10 ohms or 22 ohms. A high value resistor may be 100,000 ohms, 330,000 ohms 1,000,000 ohms or even higher.
This is an enormous range and we need this range for electronics. If we had a resistor of each value from 1 ohm to 5 million ohms we would need 5 million types! This is impractical and the designers of circuits have found that in most cases, the value of a resistor can be 10% higher or lower than a specified value and the circuit will work perfectly ok. So the manufacturers of resistors worked out a range of values to provide designers with a complete coverage without the need for too many types.
This is called the range of **PREFERRED VALUES** and starts at 10 ohms (there are also lower values). The next value is 12 ohms, then 15 ohms, 18 ohms, 22 ohms, 27 ohms 33 ohms 39 ohms 47 ohms 56 ohms 68 ohms and 82 ohms. This is the first 12 values and they may seem like unusual values but each value has been worked out on a 10% tolerance scale. The next values are 100ohms, 120 ohms, 150 ohms, 180 ohms and you can see a pattern emerging - they follow the first group except they are ten times greater. Each group is called a decade and the next decade is 1000ohms, 1200 ohms, 1500 ohms, 1800 ohms etc.
In the old days, when a manufacturer made a batch of resistors, he could not control the final value. So he simply made resistors and tested them just before adding the bands of colour. He did not want to throw any resistors away so when making 100 ohm resistors, for example, he had some at 100 ohms, some at 101 ohms, some at 125 ohms, some at 80 ohms and lots of other values.
Every resistor between 90 ohms and 110 ohms would be banded as 100 ohms. Resistors from 111 ohms to 133 ohms would be banded 120 ohms and in this way the value of any resistor would be either the exact value or only 10% away from the exact value. In electronics, most circuits will work perfectly ok with a resistor that is slightly higher or lower than the stated value. Electronics is not that critical. We are really talking about the old days of radio and the use of valves - where the resistor values were not very critical. Modern electronics (digital electronics) is somewhat more critical and resistors are much more accurate as you will see by the gold band on the resistors in the kit. Gold represents a tolerance of 5%.

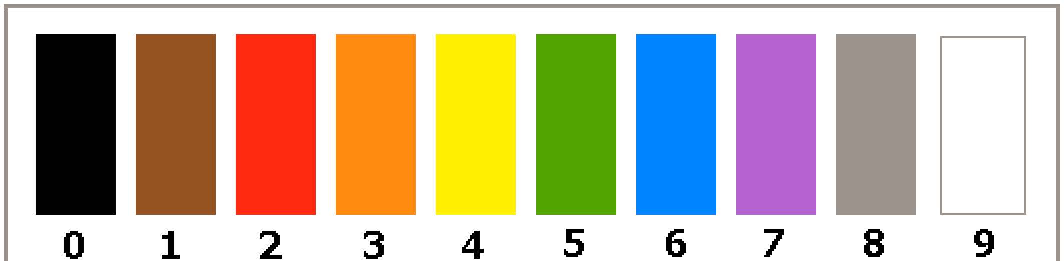
RESISTOR COLOUR CODE

Resistors have always been the most difficult component to identify in electronics and that's why they need a lot of study. Once you master the colour code you will feel much happier.
To the casual observer, any circuit board is a mass of "little coloured things" called resistors, with no indication of what value they represent. Once you know the resistor colour code you will be able to work out the values and relate them to a circuit diagram.
That's why it is so important to master this part of electronics. The resistors required for the

experiments in this section are contained in a kit of parts and must be separated from the rest of the components and correctly identified.
This is the first thing you will be doing so you don't fit the wrong value in any of the projects.
If you fit the wrong value, the circuit may not work and some of the other components may be damaged. Later on you can experiment with changing resistor values but at this stage you should only fit the specified values.

IDENTIFYING THE RESISTORS

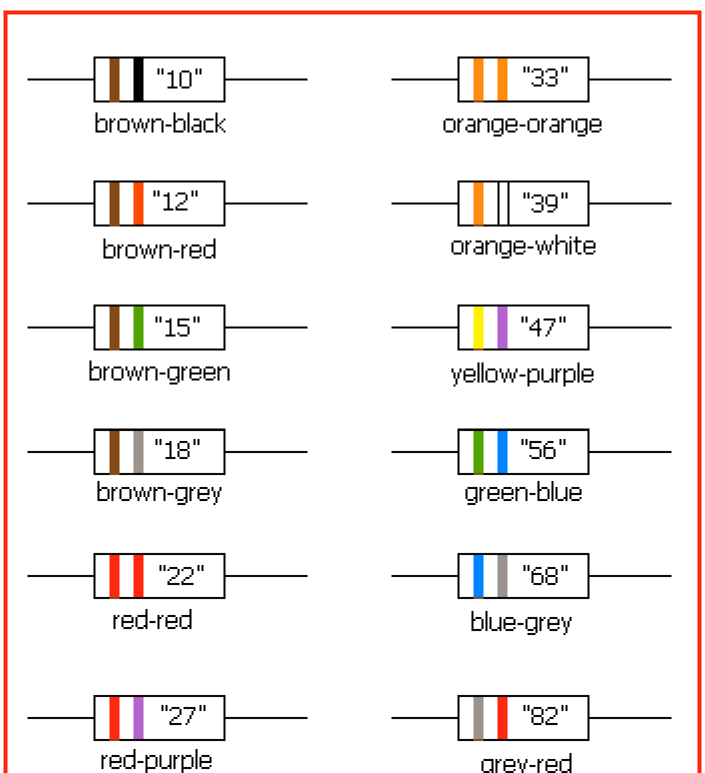
Separate the resistors from all the other components and place them on the bench so that the gold band is to the right.
The gold band indicates the resistors have a tolerance of 5%. In other words they are more accurate than older-style 10% types. This gold band does not concern us in this course but it DOES tell us which way around to hold the resistor so that the colour bands can be read correctly. Only 10 different colours are used for ALL resistors.
The following table shows these 10 colours and the number given to each:



THE RESISTOR COLOURS

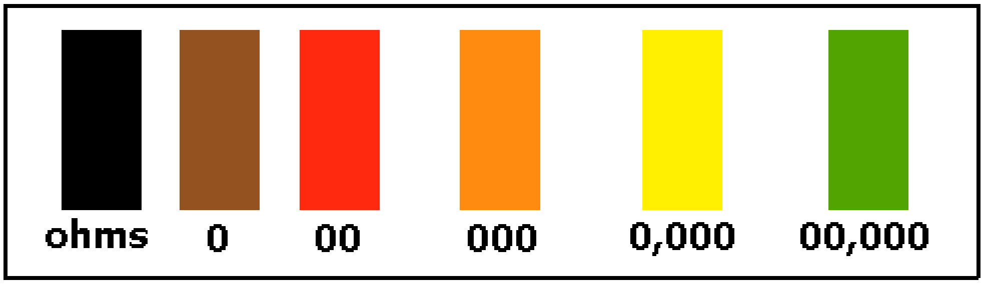
READING THE VALUES

Hold the resistor so that the 3 colour bands are to the LEFT and the right hand band is either gold or silver.
The first colour gives the first DIGIT of the resistance. The second colour give the second DIGIT in the answer. The third colour gives the number of zero's in the answer. There are only 12 resistors in each decade and they have the following first two colours:



THE 12 VALUES FOR THE FIRST TWO COLOURS

All you have to do is add the number of zero's to get the resistance. Use this table to give the number of zero's:



For example, what is the value of a resistor with colour bands:

red red black
2 2 Ohms

Answer:
22 ohms. This is written 22R

What is the value of a resistor with colour bands:

red red red
2 2 00

Answer:
2,200 ohms. This is written 2k2

A resistor with colour bands:

yellow purple orange
4 7 ,000

This is written 47k.

A resistor with colour bands:

orange white brown
3 9 0

This is written 390 ohms or 390R.

STANDARD FORM

To make it easy to recognise the value of a resistor, it is important to present the value in a STANDARD FORM - an easily recognised form. This involves using the letters: R, k and M to represent ohms, kilo ohms and Meg ohms (instead of writing lots of ,000's).
For example a 4,700,000 ohm resistor is 4.7 Meg and the decimal point is replaced by the letter M to give 4M7.
A 2,200 ohm resistor is 2.2k and this is written as 2k2. A 100,000 ohm resistor is written as 100k.
A 10 ohm resistor is written as 10R, as the letter R represents ohms. The letter R was possibly chosen as a short form of "Resistance."
A 2.2 ohm resistor is written as 2R2. A 1,000 ohm resistor is written as 1k, and so on.

WHAT DOES A RESISTOR DO?

This is not an easy question to answer because a resistor is able to do many things, depending on where it is placed in a circuit, its value and the surrounding components. Every resistor carries out a particular task, and sometimes it does more than one task.
To keep things simple we will cover only a few tasks. In future pages we will cover more features.

1. ZERO OHM RESISTORS AS A LINK

We have already shown that resistors are marked with coloured bands to show the value of the resistance in OHMs and they have a value from .22 ohm (actually from zero ohms - a zero ohm resistor is used as a LINK on a PC board and the purpose of this component may be to act as a bridge to jump over other tracks on the board or it may be a temporary component that can be removed and changed at a later date. It can also be a "test point" where the resistor (link) is removed for testing or calibration.
Resistors can be as high as 10M or greater, depending on the purpose.
This is an enormous range and depending on the value of the resistor and the other component(s) around it, so its function will be determined.

2. THE RESISTOR AS CURRENT LIMITING

Whenever a resistor is placed in a circuit, the current flow through that part of the circuit will be less when the resistor is fitted.
Some components, such as Light Emitting Diodes, will take too much current if they are connected directly across a battery or power supply.
To prevent them burning out, a resistor must be connected in series with one of the leads.
This has already been covered in previous pages.

3. THE RESISTOR AS A VOLTAGE DIVIDER

The resistor can also act as a voltage divider. When two resistors are placed in series, the voltage at their join is a percentage of the voltage across them. The actual voltage can be determined by mathematics or experimentation. For example, If two equal-value resistors are connected in series to a 12v supply, the voltage at their mid point will be 6v. The value of the resistors can be adjusted so that the "pick off" voltage is 9v, or 11v or any voltage up to 12v.

4. THE RESISTOR IN A TIMING CIRCUIT

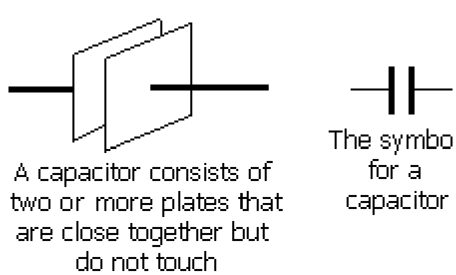
The resistor can also be used to create a TIMING CIRCUIT by combining it in series with a capacitor. This will be covered later in the course.
The resistor limits the current into the capacitor so that it takes a PERIOD OF TIME to charge.
Whenever you see a resistor and capacitor in series you can be fairly certain they form a timing circuit. There are lots of other functions for a resistor including a fusible resistor that is simply designed to burn out if the current through it gets too high, and these will be covered in future pages.

THE CAPACITOR

The capacitor is used in almost every electronic circuit. It is a very important component and it does many different things, depending on where it is placed.

A capacitor is basically a device that stores a charge of electricity.
It has two or more plates that are separated by air or a non conducting medium such as plastic.

A basic capacitor is shown in the diagram below with the corresponding circuit symbol.



Capacitors can be large or small and the size is the result of the value of the capacitor as well as the voltage it is capable of withstanding.

There is a lot to learn about capacitors and we will only be discussing the very basics.
There are many types of capacitors, here are 5 of the most common types:

AIR - such as a tuning capacitor in a radio.

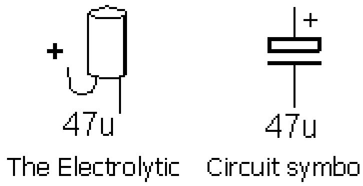
GREENCAP - a polyester capacitor.

CERAMIC - a ceramic insulating material that produces a very compact capacitor

MONOBLOCK - also called monolithic - a multi-layer ceramic capacitor

ELECTROLYTIC - aluminium plates with a moist insulating medium. This type of capacitor has a very high capacitance in a small space.

The diagram below shows a single-ended electrolytic, suitable for mounting on a printed circuit board and the symbol.



The unit for capacitance is the FARAD. But one Farad is an enormous value and we don't use values this large in electronics. The value we use is the micro-farad. A microfarad is one-millionth of a farad.

For some circuits we need capacitors of more than 1 microfarad capacitance and for others we need less than 1 microfarad.

For a power supply we need electrolytics of 10 microfarad, 100 microfarad, 1,000 microfarad and even 10,000 microfarad. The letter to signify microfarad is "uF" or simply "u". Thus 1microfarad is 1u, 10 microfarad is 10u etc.

For audio work we need smaller values such as .1microfarad and .01 microfarad.
In electronics, we try and avoid using the decimal point as it can be rubbed off components and omitted from photocopies of circuit diagrams.

To get around this we use sub-multiples and the sub-multiple of microfarad is nanofarad.

1,000 nanofarad = 1 microfarad.
Thus .1u = 100 nanofarad.
The letter to represent nanofarad is "n".
Thus .01u = 10n

For radio frequency work, even smaller values of capacitance are needed.

The nanofarad is divided into 1,000 parts called picofarad. Thus 1,000 picofarad = 1nanofarad.

The picofarad is written pF or simply "p."
Thus 1,000p = 1n.

Some capacitors are physically very small and there is very little space to write the component value. To get around this, manufacturers have produced a numbering system using 3 digits.

It is based on picofarads. A 100 picofarad capacitor is written as 101, A 1,000 picofarad capacitor is written 102, A 10 nanofarad capacitor is written 103 and 100 nanofarads is written 104. The third digit represents the number of zero's.

For example: 1n = 1,000p = 102.
10n = 10,000 = 103
100n = 100,000 = 104

WHAT DOES A CAPACITOR DO?

Capacitors do lots of things and it depends where they are positioned in a circuit, the value of the surrounding components and the value of the capacitor.

One of the things that makes the study of a capacitor complex is the current flowing into it starts off very high and gradually reduces as the capacitor charges.

In addition, the voltage across the capacitor does not increase evenly, it rises rapidly at first then gradually slows down. Some of these facts have already been covered and at this stage it only important to know that the charging is not linear.

The capacitor can also be used as a timing component. This has been covered in the oscillator circuits where the value of the capacitor determines the frequency of the oscillator.

The capacitor is basically a device that stores a charge of electricity, but depending on where it is placed in a circuit, it can be used as a reservoir device, a blocking device or a device to pass AC signals. It can be used for filtering, stage separation, decoupling, timing, and even amplifying! (In a tuned circuit it creates amplification when connected to a coil - but this is mainly due to one of the incredible properties of a coil).

It will take a lot more projects to cover all these features.

You can **hear** the result of a time delay circuit in the Simple Siren project (Project 4) and if you think of the electrolytic as a miniature rechargeable battery, charging and discharging as we have shown in the animations, you will be a little closer to "seeing" how the circuit operates.

THE LIGHT EMITTING DIODE

In this set of projects, a small light emitting device is used in projects 1, 2, 3 and 4 to show that a circuit is working. It looks like a very tiny red or green globe but in fact it does not have a filament and does not get hot - so it's not a globe. It's a solid-state device that never burns out and consumes very little current. It is called a Light Emitting Diode or LED for short.

5mm Red LED **3mm Red LED**

It is one of the most amazing electronic devices to be invented and you will have seen it used in flashing tail lights for bicycles and as "ON" indicators for electronic appliances and in many types of 7-segment number displays.

Even though this component looks very simple it has a number of requirements that have to be met to make it work properly and that's the purpose of these experiments.

Here are some of the characteristics and requirements of a LED:

A LED must have a resistor in series with one lead to prevent it burning out.

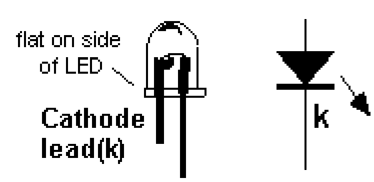
A LED will only work when connected around the correct way.

A LED produces a characteristic voltage across its terminals and this voltage is constant, no matter how bright the LED. The voltage is 1.7v for red LEDs, 2.1v for green and 2.3v for orange LEDs. This voltage is slightly higher for some LEDs, depending on the manufacturer and **High Bright** devices have slightly different characteristic voltages. But for our particular devices, it remains constant.

A LED can be turned on for a very short period of time and your eye will extend the time (due to a phenomenon called **P**ersistence **O**f **V**ision). That's why we can pulse a LED very briefly and repeat the process at a high frequency and the LED will appear to be ON all the time.

The only thing you cannot get from a LED is white light. You can get red, green, yellow, orange or blue, but not white. The colour is determined by the crystalline material used in the centre of the LED. The casing or body is sometimes red, green or orange etc to help enhance the colour of the emission from the crystal and this is called a diffused LED. If the body is clear, the colour produced by the crystal will depend on the type of crystal giving off the illumination. White light cannot be produced by a single emission - the only way to get nearly white light is to combine red, blue and green LEDs together and the eye will merge the colours to get white.

The symbol for a LED is shown below:



The symbol for a LED. The arrow indicates light is given off.

The line on the diagram corresponds to the cathode lead and this is generally the shorter lead.

You cannot always be certain of this as we have found some LEDs are made in reverse or sometimes the two leads are the same length.

When we are talking about the leads, we do not describe them as "positive" and "negative" we only say anode and cathode. Most of the time we only refer to the CATHODE lead.

A small flat on the side of the body of a LED indicates the cathode lead - this is very helpful to remember as it identifies the correct placement of the LED when fitting it to a project.

If you do not know which lead is the cathode, connect it to a 9v battery with a 220R or 470 ohm resistor **in series** with one lead. The LED will illuminate when the cathode lead is connected to the negative terminal of the battery.

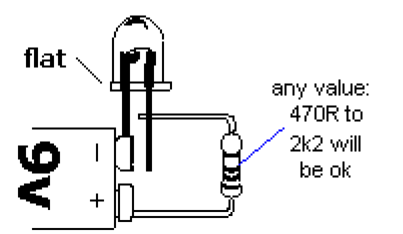
The normal current required by a LED is 10mA (milliamp). The LED will still operate on currents as low as 1mA and the maximum continuous current is 25mA.

For a particular current flow, some LEDs are brighter than others. This is due to their efficiency. Light output is measured in milli-candella. Most LEDs have an output of about 20mcd and these are used as "ON" indicators. Better quality LEDs are 100, 200 and 500mcd and these are called **High Bright**. Super High Bright LEDs have an output of

500mcd, 1,000mcd, 2,000mcd and 5,000mcd. 5,000mcd = 5 candella and these LEDs produce a light beam suitable for a key-light torch.

TESTING A LED

Before fitting the LEDs to the projects in this e-book, they can be tested to find the cathode lead. Simply connect one of the 220R or 470R resistors to one of the leads and connect to a 9v battery as shown in the diagram.

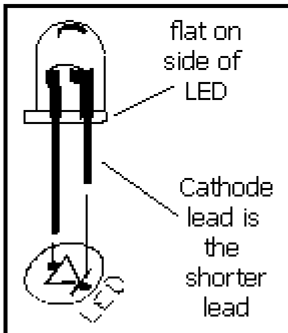


Testing a LED. The LED will illuminate when it is around the way shown in the diagram. The flat on the side of the LED indicates the cathode lead.

If the LED does not illuminate, turn the LED around. This testing will not damage the LED. (Do not connect the LED directly across the 9v battery as this will damage the crystal inside the LED.) When the LED illuminates, the cathode (k) lead of the LED will be connected to the negative terminal of the battery.

FITTING A LED

The LED is fitted to the PC board so that the cathode lead (the shorter lead) goes down the hole marked with the line on the overlay. Refer to the diagram



FITTING A LED

Sometimes a small flat can be seen on the side of the LED but this is very hard to find on 3mm LEDs. The best is to reference from the shorter lead but if you have cut the leads, you will have to test the LED as shown above before fitting it.

Don't forget to solder LEDs very quickly as they can be easily damaged when soldering and their light output will be reduced.

THE TRANSISTOR

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s

The transistor is a 3-leaded electronic device. The three leads are given the names: **COLLECTOR**, **BASE** and **EMITTER**.

In simple terms the input lead is the **BASE** and the output is the **COLLECTOR**.
The **EMITTER** is connected to the negative rail (for an NPN type) and is common to the input and output.

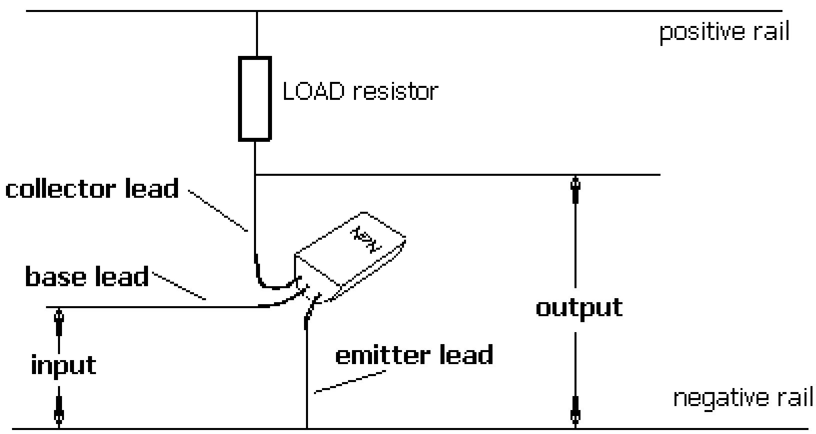


Fig 1: The transistor is a 3-leaded device. The input is between the base and negative rail. The output is between the collector and negative rail. The negative rail is also called the 0v rail.

A typical transistor is shown in Fig: 2 with the equivalent circuit symbol:

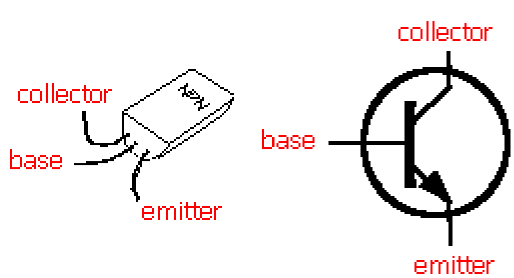


Fig: 2. The NPN transistor

The transistor is an amplifying device. It has a very close analogy to the water transistor show in Fig. 3.

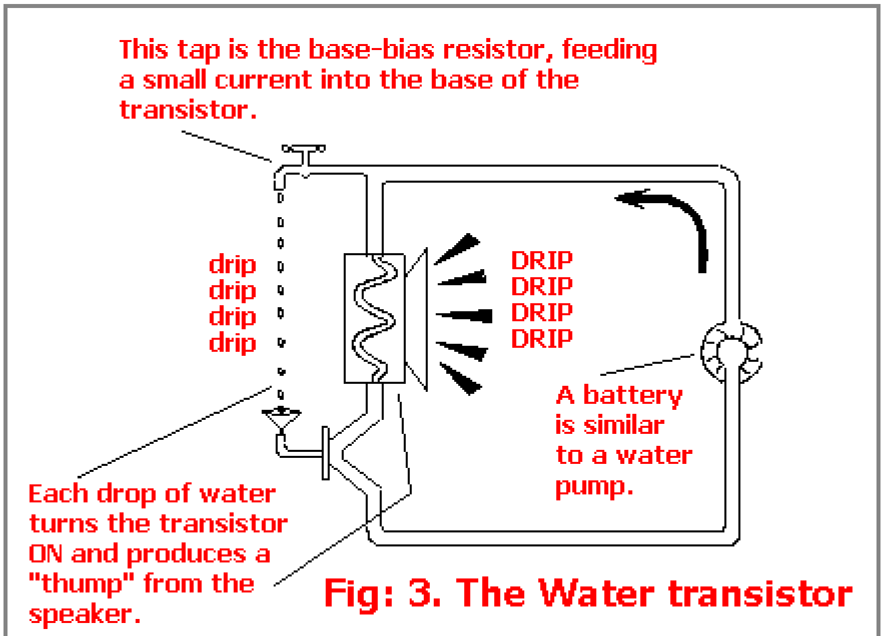


Fig: 3. The Water transistor

Each drop of water that enters the base "turns" the transistor on and causes a larger amount of water to flow through the speaker to produce a loud "thud" or "click."

This is why the transistor is called an amplifying device.

The only unusual feature with a transistor is the base must be fed with a small amount of voltage (.6v) before the transistor will allow current to flow.

This can be equated to putting a few drops of water into the funnel and then further drops will create a thud.

In general, we can consider the transistor is capable of amplifying 100 times. In other words, if 1mA is fed into the base, 100 milliamps will flow in the collector-emitter circuit.

Transistors are also capable of amplifying very small currents. If 1/1,000th of a milliamp is fed into the base, the current flow in the collector will be 1/10th of a milliamp.

PNP AND NPN TRANSISTORS

There are two types of small-signal transistors. One is called NPN and the other is PNP. These names are derived from the type of material used in the manufacture of the junctions.

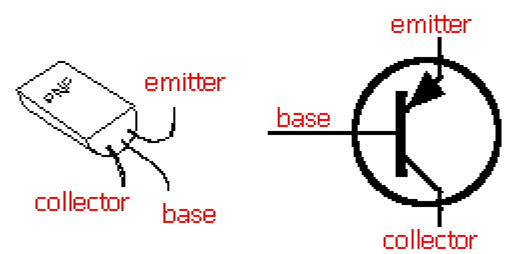


Fig: 4. The PNP transistor

The PNP type is a mirror image of the NPN type and you will see that the NPN type is generally connected with its emitter lead to the negative rail while the PNP has its emitter connected on or near the positive rail as shown in fig. 5.

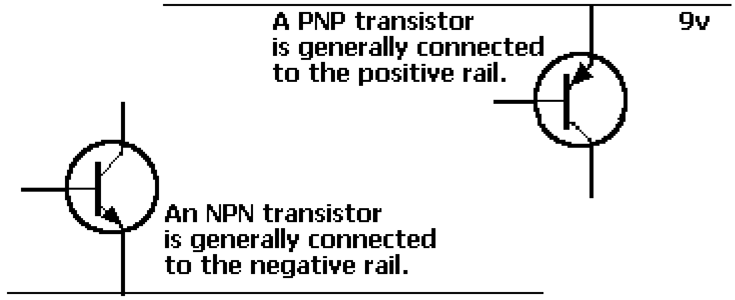


Fig: 5 How NPN and PNP transistors are generally connected to the power rails.

It is very important not to mix up PNP types with NPN types as NPN types will not work in place of a PNP type and vice versa.

IDENTIFYING THE TRANSISTORS IN THE KIT

Because this e-book is available world-wide on the web, the type of transistors you can purchase locally may be different from those we have described. If you buy a kit locally, the transistors supplied may be substitutes. They will work exactly as discussed but the pinout may not be included in the kit. Contact us if the pinout is not included and we will add it to the table.

We have concentrated on the fact that one of the transistors is a PNP type and the other is NPN. The circuits we have described are not critical in operation and will accept almost any type of small signal transistor - providing they are PNP or NPN.

For a beginner it is not nice to be given an unbranded component or one with a coloured dot on it but in our case the circuits are so flexible that the most common types in each country will work perfectly ok.

In the parts list and on the circuit symbols page we have given a list of transistors for each type and the first thing you should do is mark the top of the PNP transistors with red nail polish and the NPN transistors with white-out. This will keep them separated as it is very easy to make a mistake and fit the wrong type of transistor.

If we have supplied a transistor not included on the list, we will have already marked it with a white dot for NPN and red dot for PNP so that a mistake cannot be made.

WHY WILL ANY TRANSISTOR WORK?

Almost any transistor will work in our circuits because we are using them in a non-critical way, on a low voltage and not expecting an impressive performance. When transistors are manufactured, they are made in very large batches. They are then tested for collector-emitter breakdown voltage, current gain as well as a number of other parameters. Every device is then given a type-number and even those that are left over from the "batching" process are ok for the circuits in this book. Sometimes you can get unbranded transistors in junk packs and these will also be suitable.

If you are using parts from your parts-box, the only thing to remember is to find 4 NPN transistors and 2 PNP transistors. You will also need to know the pin-out of the leads. .

TRANSISTOR PIN-OUTS

Fortunately transistors have only three leads however there are 6 different ways of naming these three leads and that's exactly what different manufacturers have done.

Most of the time the pin-out is a result of the way the transistor has been fabricated however it is important to know the pin out of the devices you are using as it will take a lot of soldering and desoldering to try all the different combinations.

We have provided diagrams for the most common devices and a pin out will be included with any devices used in our kits if they are not on the list.

BIASING A TRANSISTOR

There are two resistors that must be connected to a transistor so that it will work. These are the base-bias resistor and load resistor. For an NPN transistor, fig 6 shows the placement of the two resistors:

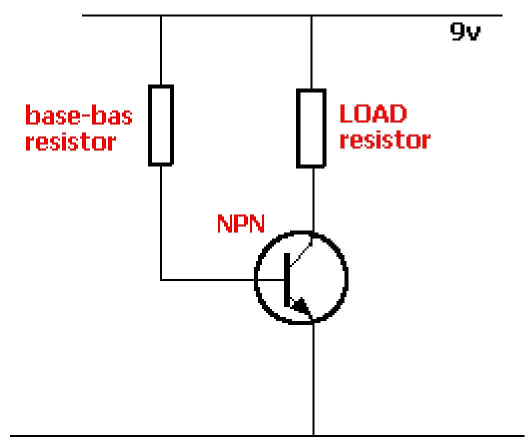


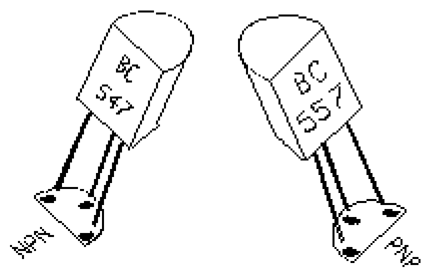
Fig: 6. The base-bias resistor and LOAD resistor for an NPN transistor.

In Project 1, the base-bias resistor for the NPN transistor is the touch plate (plus the 47k) and the load resistor is 1k.

The base bias resistor is a very high value so that only a very small current flows into the base. This is all the transistor needs as it amplifies the base current at least 100 times and allows the higher current to flow through the LOAD resistor.

FITTING A TRANSISTOR

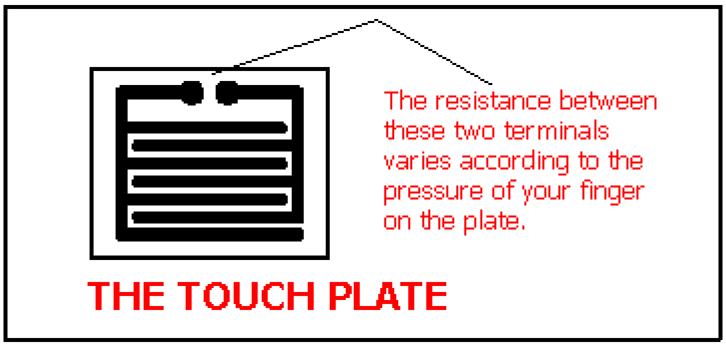
The overlay on the PC Board has a "D" shape showing where each transistor is placed. The transistors we will be supplying in the kits will fit exactly over this shape and the leads will fit down the three holes. The diagrams below show how the transistors fit down the holes. If you have transistors other than BC 547 or BC 557, the shape of the transistor will be slightly different and the leads will be in a different position. Refer to the notes contained in your kit.



Fitting the BC 547 and BC 557 transistors to the PC board

THE TOUCH PLATE

The touch plate is the section at the end of the printed circuit board.
The first thing you must do is cut it off so it can be used for the projects.



This is done by cutting along the line with a hack saw or sharp knife. Some boards have a row of small holes to make separation easier while others have a score-line to allow the board to be "snapped off."

The track-work for the TOUCH PLATE looks like two interleaved combs. It will be connected to the projects via two leads and used as a "touch sensor plate" or "rain alarm."

If you study the tracks on the board you will find they are very close together BUT THEY DO NOT TOUCH EACH OTHER. This is equivalent to two long, bare wires running parallel to each other, then folded back-and-forth to take up the least area. When you touch any part of the plate with a finger, you touch both the tracks at the same time and the resistance between them decreases. To understand this you will have to know a little bit about the term RESISTANCE.

Resistance is measured in OHMs and when something is a good conductor it has a low resistance. In other words it has only a few ohms resistance.
When something is a bad conductor it has a high resistance. In other words it has a resistance of many ohms, sometimes thousands of ohms or even millions of ohms.

The resistance between the two tracks on the touch pad (when not being touched) is many millions of ohms. When you touch the plate, the resistance reduces to about 100,000 ohms. When you press harder, this decreases to 50,000 or 30,000 ohms.

When the plate is connected to a circuit, the change in resistance is detected by the circuit and a certain amount of current flows. This current is very small and the circuit amplifies this current. In one of the projects the touch pad is used to turn on a LED. In another project it is used to alter the flash rate of a LED and in project 5 the touch plate is used to change the tone of an oscillator.

When you press harder on the plate, the resistance decreases. This is because more of your finger touches the tracks and more moisture comes out of the pores of your finger. It is the MOISTURE IN YOUR FINGER (the salts in the moisture) that causes the

resistance to reduce.

The touch plate can also be used as a rain detector (experiment 5). When a drop of water falls on the grid, it touches the two tracks and reduces the resistance between the terminals. Pure rain water is non conductive however as the droplets fall through the air they pick up small amounts of carbon-dioxide and other impurities and this makes the water slightly conductive.

The interleaving grid pattern has been chosen as it effectively multiplies the resistance of your finger, or in the case of the rain drop, the conductivity of the rain drop by allowing a large amount of the printed track-work to come in contact with the drop of water.

This type of pad was one of the earliest forms of touch switch and was used in a number of electronic devices in place of a push button. It was one of the first attempts at a vandal-proof switch or trouble-free switch, however it suffered from one major problem. If residue was left on the pad, such as jam, butter or oil from the skin, it became less effective.

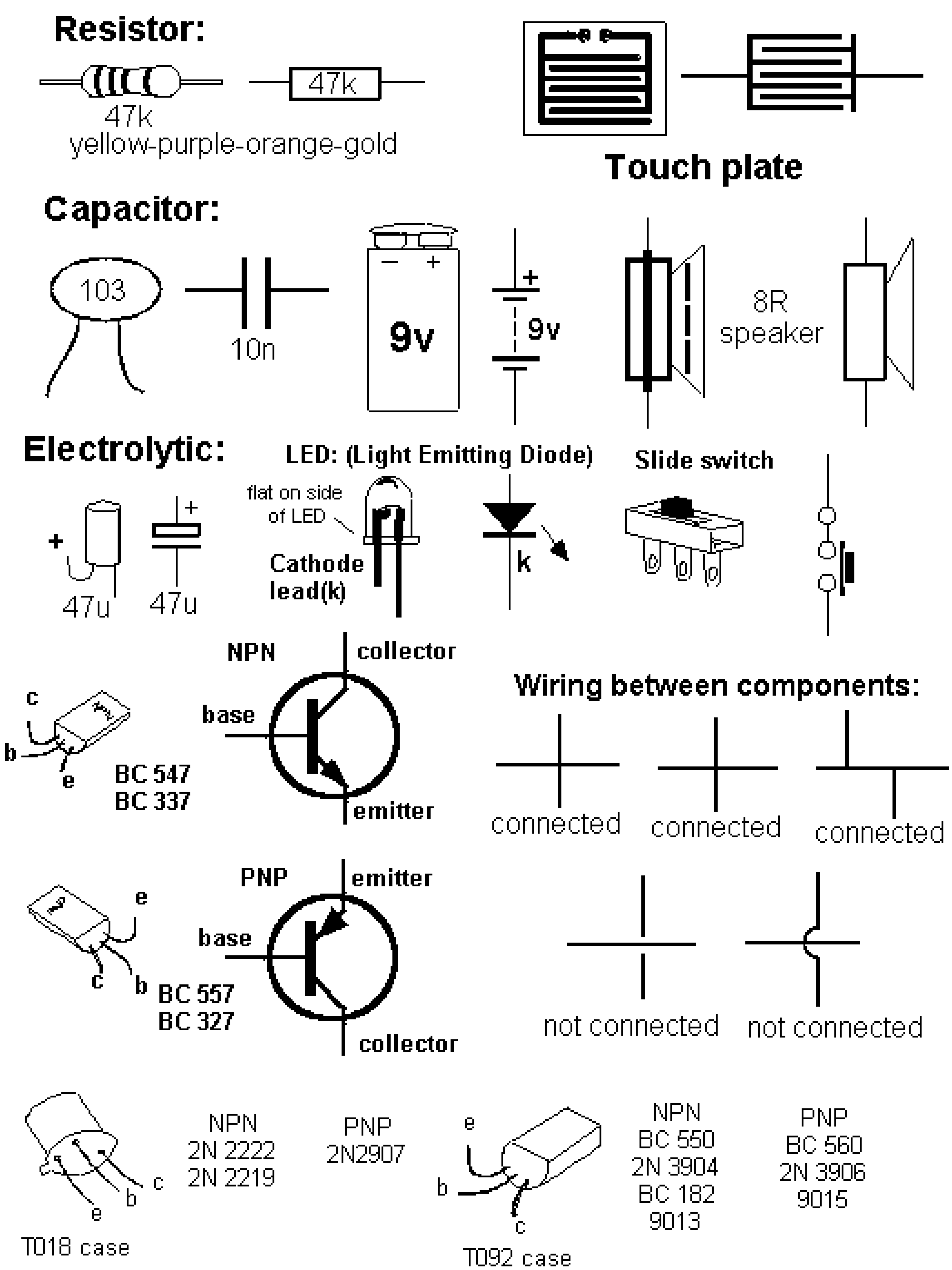
In addition, it did not work successfully for all type of users. The effectiveness of the pad depends on the amount of moisture in the finger and it will not work very effectively with a very dry finger.
If your pad does not work as described in any of the experiments, try moistening your finger slightly and see the results improve. Touch plates have now been replaced with membrane switches in most electronic devices. Membranes require only very slight pressure for their operation and no dirt can enter the sealed switch, but a touch pad is a very good way to show how the resistance of your skin changes with pressure and moisture content.

This is important because electrocution is much more severe when the body or hand is wet or when you are pressing heavily on exposed wiring etc. But don't worry about this in any of our experiments, the voltage is so low that none are dangerous at all.

SUMMARY

The touch plate is similar to a variable resistor. In other words it is a resistor in which the resistance can be altered.
The resistance of the touch pad is very high when not touched and its resistance reduces when touched. The harder you press, the lower the resistance between the terminals.
When used in the siren circuit, the lower resistance produces a high tone and when used in the LED flasher circuit, the LED will flash faster when you press hard on the plate.

CIRCUIT SYMBOLS



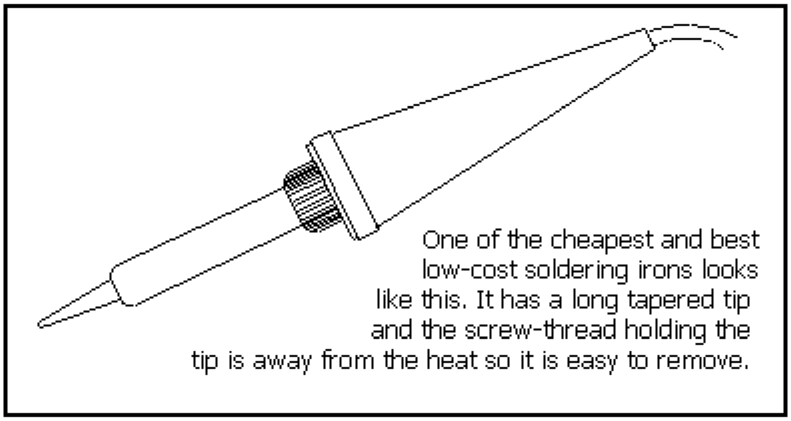
SOLDERING

THE ART OF SOLDERING

The art of soldering takes months, if not years, to master and every time you build a project your skills improve.

If you have experience with soldering, you will have no trouble putting together the projects in this e-book. But if you are new at electronics, you will need a lot of help. This chapter covers the points to look for in a good soldering iron and how to make a perfect solder-joint. Read it carefully as we have presented some information and hints that have never been covered before.

The first hint: The best way to prevent damaging a component when soldering is to hold it in your fingers, while holding and pushing it onto the printed circuit board.

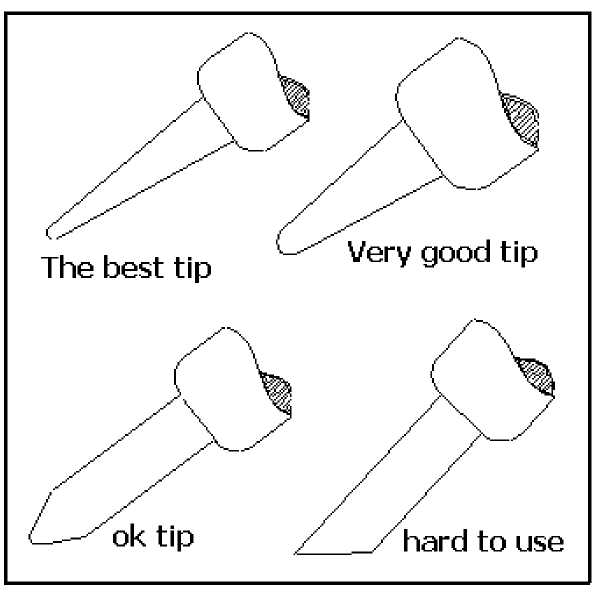


If you have to let go, the component is getting too hot. This applies especially to transistors and LEDs as they are semiconductor devices and must not be allowed to get too hot as they can be easily damaged - more about this later.

BUYING A SOLDERING IRON

There are lots of soldering irons on the market and they cost from a tiny $5 to a massive $1,000!

What's the difference between them and which one is best for a beginner?



This is a complex question and difficult to answer without seeing the range of irons. But one thing I can say is the expensive irons are very nice to work with and have a variable temperature control that makes your soldering very neat and professional.

If you intend to make electronics your hobby and eventually your profession, I suggest you invest in a temperature controlled soldering STATION and you will have the best from the start.

If you are not able to spend a lot of money at this stage, any of the low-cost soldering irons with a rating of 15 to 30 watts will be suitable. Don't buy a plumbers-type soldering iron with a rating of 60 watts or greater or an instant-heat soldering iron or a soldering gun as they require a lot of skill to get the correct temperature and you can easily damage delicate components.

All the low-cost irons require a lot skill to use. Most of them get too hot and you have to be very fast at soldering to prevent damaging components. It takes a lot of skill to make a fast connection and that's why it is easier to use a temperature-controlled soldering station. Apart from the correct temperature of the iron the size and shape of the tip is a very important consideration.

THE SIZE OF THE TIP

Sometimes a very fine tip is what you need to make a delicate joint and sometimes a small flat on the end of the tip is handy for adding solder to a larger connection.

The actual shape does not matter but as you get more experienced you will find the screwdriver-type tips as shown in diagram 4 are not very nice to work with and a tapered tip with a fine point as shown in figure 1 or medium point as shown in figure 2 is professional-looking and good for all types of connections.

Anything larger than this, as shown in figure 3 and 4 will not allow you to get into tight areas - especially when soldering surface-mount components (we will have a surface-mount project later).

In theory you could use a rusty nail to make a perfect solder joint, provided the nail was properly tinned before starting the job. But before we discuss the art of tinning the tip, we must mention another important item - the solder.

SOLDER

You may think solder is an insignificant part of soldering but it is actually a highly technical item and some of the factors associated with solder help you create better joints.

There are three points we will be covering: They are:

1. How does solder work?
2. What are the melting points for solder? and
3. How does flux work?

Solder is normally a tin-lead alloy, although other elements such as Copper, Silver, Bismuth, Indium, Antimony and Cadmium can be added to obtain certain characteristics.

Solder has three distinct states:

SOLID, PLASTIC and LIQUID

The solid and liquid states are easy to understand but the plastic region needs a little explanation. This is when the solder is beginning to change from a liquid to a solid. You can see this occurring on a joint when the shiny surface gradually becomes dull. When solder is cooling through this region, the joint must not be moved otherwise the wire or lead forming part of the joint will be very weak when the solder has cooled down. In fact if you wiggle or pull the lead it will easily come away from the joint.

This is basically how dry joints occur. If a component such as a transistor, regulator or resistor gets hot enough to pass heat down its lead and the lead melts the solder joint, the result will eventually be a dry joint, even though the original joint may have been perfect. The other condition that has to occur is the component must not be moved (such as vibration) while this solder is cooling. The result will be a fracture in the solder.

Lead melts at 327°C/621°F and tin melts at 232°C/450°F. But most of the tin/lead alloys change from solid to plastic state at 183°C/361°F.

The plastic region occurs between these two states and its width varies according to the tin/lead ratio.

At the 63%tin/37%lead ratio, the alloy passes from solid to liquid with no plastic region. This is termed a Eutectic alloy and the temperature at which this occurs is called the Eutectic point (183°C).

63/37 solder is not normally used in electronics as it is very susceptible to fracture at the instant of solidification due to any slight movement of the solder joint.

60/40 solder is the most commonly used as it has a very small plastic region of 5ºC (183ºC to 188ºC) and with a little care, a good solder joint is easy to make.

Solders with less than 60% tin do not wet the base metal as good as higher tin solders. They are more brittle and more likely to fracture under stress.

50/50 solder has a relatively large plastic range of 29°C, therefore more care must be taken not to disturb the joint when cooling.

When soldering, a certain amount of the base metal is absorbed into the solder. Usually this is not a problem, but if it is, special solder alloys can be used to reduce the effect.

For instance 50/48.5/1.5 (Sn/Pb/Cu) (Tin/Lead/Copper) solder will reduce the absorption of copper from unclad soldering iron tips but since most soldering iron tips are triple plated, this should not
be necessary. As soon as the tip gets a hole through the plating it should be replaced with a new one.

FLUX

The diagram above shows a solder land on a PC board.

This land can be bare copper or pre-tinned with solder or nickel plated (nickel plated lands are very hard to solder). The lead of a resistor is usually plated mild steel. They are not, as you would expect, made of copper as this is very expensive and to reduce the cost of components
they are a ferrous metal with a plating of nickel or tin.

All these metals form an oxide layer when exposed to air and quite often they get oil and grease from fingers and the surroundings.

This oxide layer is a barrier and prevents the solder sticking to the metal. The problem becomes worse when the metal is heated as the heating accelerates the formation of the oxide layer.

This is where flux comes in. Rosin cored solder has flux in the centre of the solder. It may be a single core of flux or 5 very fine cores.
Five-core solder is the best as it allows the soldering iron to heat up the flux before the solder has reached the liquid state, causing it to flow out of the solder and clean the surface ahead of the molten solder. Single core flux is more messy and comes out in spurts and bubbles. Avoid this type of solder if possible.

Rosin flux is obtained from the gum of pine trees and although it is not extremely harmful, you should never breathe the fumes. (When taking the enamel off winding wire the fumes are extremely dangerous in the gaseous state and must NEVER be inhaled. The best is to stop breathing when removing the enamel.)

The diagram below shows the advancing hot solder with the flux covering the copper and removing the oxide film.
A good solder joint will finish up bright and shiny with almost all the flux being evaporated during the soldering process.
If you have a lot of flux left over, either the solder is not of good-quality (such as single core solder), the iron is not hot enough or a lot of dirt is present.

It is very difficult to explain on paper how to tell if a soldering iron is too hot or too cold. But if I was next to you I could tell exactly the temperature by simply watching how fast the iron melts the solder and how fast the flux creates fumes. You will generate this skill too, after a lot of

soldering.
There's one final point while on the topic of flux. The life of rosin cored solder is about 5 seconds! As soon as the flux has evaporated from the solder, the remaining solder is ABSOLUTELY useless.

This means you must have the solder next to the joint so that the flux does its work IMMEDIATELY. It is useless melting the solder on the iron and then taking the iron 30cm to the joint. The solder is
already DEAD and cannot possibly make a good connection.

The other thing you must not do is dab, dab, dab the solder on the joint. The can leave the solder in the plastic region and can easily create a faulty connection as discussed above.

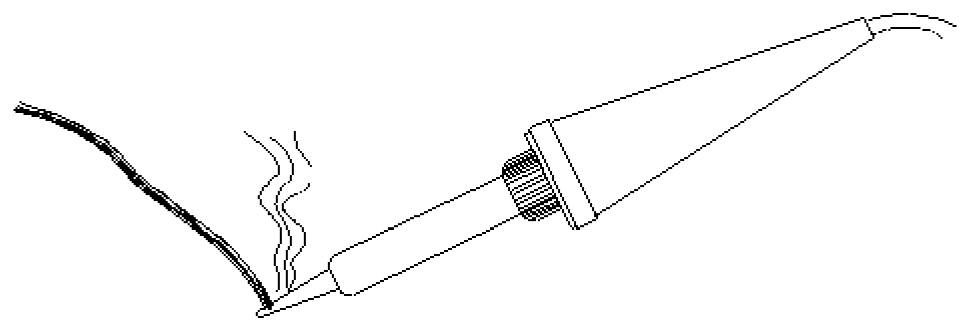
Tinning the iron is the most important part of soldering, so let's look at what we mean.

Here are the 2 simple steps to creating a good joint:

Step 1:
Tin The Iron

The size and shape of the tip does not matter, provided it is bright and shiny. The way to do this is to add fresh solder so that the resin (in the centre of the solder) does its job.

No matter what the size and shape, the first thing to do is TIN THE TIP by feeding one centimetre (1/2") of fine solder onto it and letting the resin in the centre of the solder clean the tip.



Step 1. Tinning the iron. Add 1/2cm of solder to the tip of the iron and wipe on a wet sponge.

This solder is then wiped onto a wet sponge so that no excess solder remains on the tip.

This may seem like a waste of solder but it is actually the resin (or rosin) in the centre of the solder that is required. We don't want any solder that has been sitting on the iron and that's why it is wiped off.

Do not use any type of plumbers soldering flux or solder paste or plumbers solder or any form of thick solder that comes without rosin in the centre.

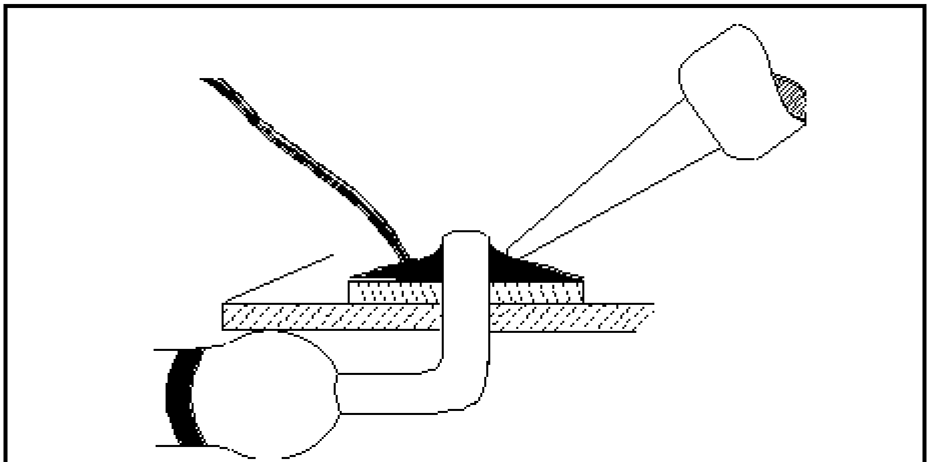
The only two types of solder for electronic work are:
Fine: .71mm and
Standard: 1mm.
This tinning procedure is done every time the iron has not been used for 15 minutes or so.

This is the secret to good soldering and unless the tip is absolutely clean (by carrying out the above process) you are simply wasting your time.

When a soldering iron is left in a hot state for 15 minutes or more, the solder on the tip oxidises and some of the resin is left behind and is burnt to a carbon compound. This solder becomes very dirty and if you try to use it to make the next connection, it will not "stick" to the lead of the component or to the track on the PC board. It will sit on the lead or the pad on the board and create a dirty joint. Later, this will become a prime possibility for a dry joint.

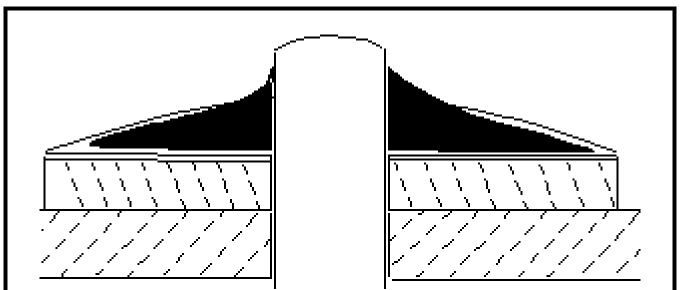
Step 2:
Heat the solder-land

The iron is then taken to the solder-land where the joint is to be made. The land and the lead is then heated for about 1 second and 1/2cm of fine solder is added to the land on the other side to the iron.



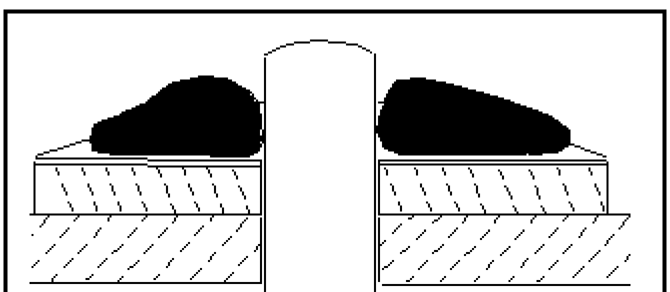
Step 2. Heat the land and lead for 1 second then add 1/2cm of solder - from the opposite side to the iron.

A good connection will have the solder licking up the side of the lead and will spread out over the solder-land as shown in the diagram below.



A good connection will look like this.

If you have not done everything correctly, the solder will not "stick" to the lead and will look like the diagram below:



A bad connection is where the solder has not "stuck" to the component lead.

THE DRY JOINT

A dry joint is the worst thing that can occur because it looks like a good connection but when the component is wiggled, the lead becomes loose and can be pulled away.

Dry joints look to be ok but they don't make a perfect electrical connection. They make a connection that is intermittent.

This is the one thing we try to avoid and that's why you have to become expert at soldering.

Dry joints can occur AFTER a product has passed inspection. If a component gets extremely hot during use, such as a regulator or output transistor, heat passes down the leads of the component and enters the joint. The solder heats up and partially melts. When the joint cools the solder does not adhere properly to the lead and a faulty connection is produced.

The only way to eliminate this is to keep hot components on long leads or heat-sink the body so that the temperature does not rise more than "touch hot."

If any joint is constantly heated and cooled, and the lead is moved when the joint is passing through the plastic region, the solder will fracture very easily. The end result will be a "dry joint."

THE SOLDERING IRON STAND

One last item to cover is the soldering iron stand. It is important, not only to prevent the iron falling off the bench, but for two other reasons. The base of the stand holds a sponge that must be wetted with water every time you begin soldering. You must wipe the tip of the iron before every connection to remove dirt and contamination if you want to make a perfect connection..

The base of the stand also has a tray to hold excess solder that has been tapped off the tip. Every time you make a connection, the excess solder must be tapped off so that new solder can be used for the next joint. You must ONLY use NEW solder for every connection.

If you cannot buy a low-cost stand from your local electronics store, a glass ashtray will do the job. It's not perfect substitute but will prevent the iron falling off the bench and hold a damp sponge. It is better than nothing.

If you follow the simple rules we have outlined, the quality of your soldering will improve and as you gain more experience with timing and manual dexterity, you will be able to handle finer and finer work.

Later in this book we will be introducing surface mount components. These components are intended for robot soldering as they are really too small to he handled manually. But with a lot of care and experience you will be able to master the art of soldering them and eventually come to accept them just like a standard component.

Soldering has come a long way in the past 20 years and if the electronics industry was still using soldering skills of 20 years ago, every computer would break down every month! That's the measure of the advancement in soldering.

Soldering has made electronics the "Science of Reliability."

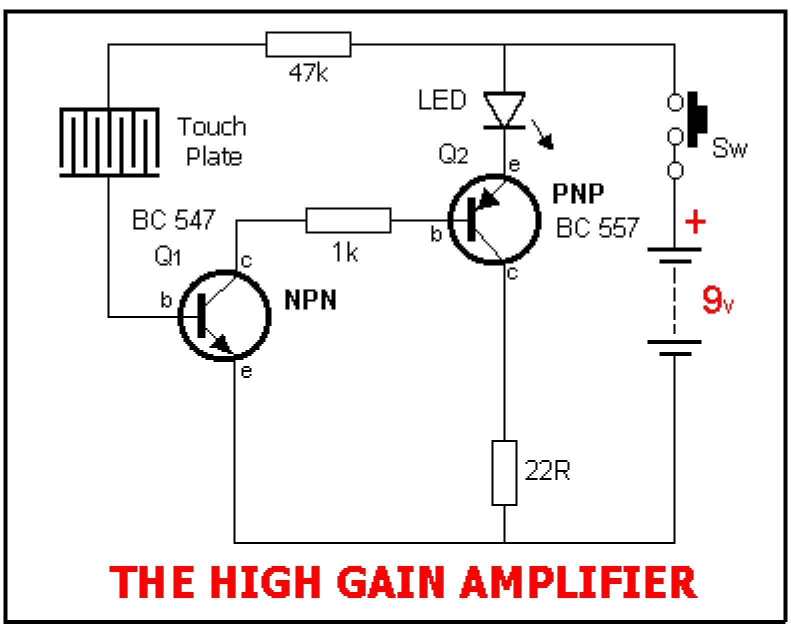
Start with this great project . . .

THE
HIGH GAIN
AMPLIFIER

Build the circuit and learn how it works
This is Project #1 on the PC board in "5-PROJECTS"

(you will also need a soldering iron, solder and side-cutters. These are available from your local electronics store)

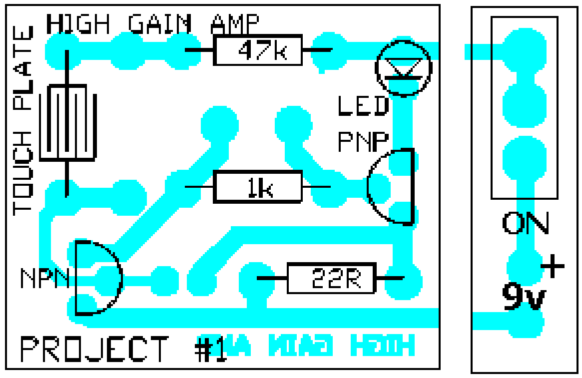
In this project a 2-transistor amplifier is built on the first section of the Printed Circuit Board and a touch plate is connected to it so that the LED turns on when the plate is touched.



This may not seem like a very impressive circuit but the first transistor is amplifying the current through the touch plate by about 200 times and the second transistor has a gain of about 50 making a DC amplifier with a gain of about 200 x 50 = 10,000!

The reason why the first transistor has a gain of 200 while the second has a gain of only 50 is a complex issue and will be covered in a future page. It is due to the position of the transistor in the circuit and the task it is performing.

If this circuit was an audio amplifier with a microphone at one end and a speaker at the other, the sound of a pin dropping on the floor would blast you out of the room! That's what a gain of 10,000 would sound like.



Enlarged drawing of PC board
showing the components for this project

Our circuit is amplifying the current flowing through your finger (when it touches the touch plate) 10,000 times and this is sufficient to illuminate the LED. The current flowing through your finger (when touching the touch plate) is only a few microamps and this is not enough to illuminated the Light Emitting Diode (LED). We need an amplifier with considerable gain to get the LED to light and this is what the circuit does.

You can alter the brightness of the LED by pressing lightly on the plate and this will show that the resistance of the plate changes with the amount of pressure you exert.

You can also moisten your finger to see how this changes the resistance of the plate and observe the brightness of the LED.

THE FACT TO REMEMBER IS THIS: As the resistance of the plate decreases, the brightness of the LED increases. In other words, as the plate allows more current to flow, the transistors amplify the current and illuminate the LED.

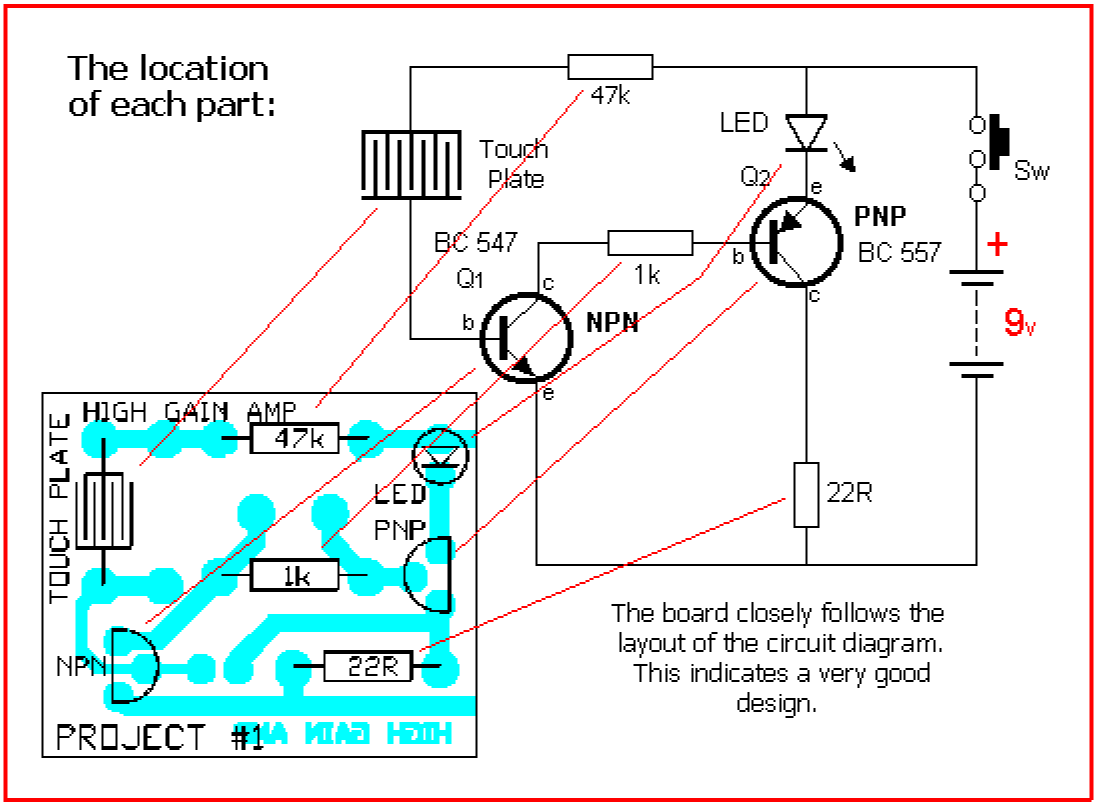
HOW THE CIRCUIT WORKS

Each component in this circuit has been discussed individually on the previous pages of this e-book. We now combine them together in a HIGH GAIN AMPLIFIER.

We start the description at the touch plate. We have already explained how the touch plate works. It consists of two interleaved tracks so that when you touch them with a finger, the resistance between the two tracks reduces.

This action allows more current to flow through the terminals of the touch plate and since it is connected to the base of the NPN transistor, more current flows into the base.

The transistor is a current amplifying device and it will amplify the base current by at least 200 times.
The diagram below will assist you to see this. The resistance between the collector and emitter leads of the NPN transistor reduces and a "turn-on" circuit is produced for the PNP transistor by the action of the NPN transistor, combined with the 1k resistor.



These two components form a base-bias resistor for the PNP transistor and the base of the PNP is turned on. This causes the PNP transistor to turn on and current flows through its emitter-collector leads.

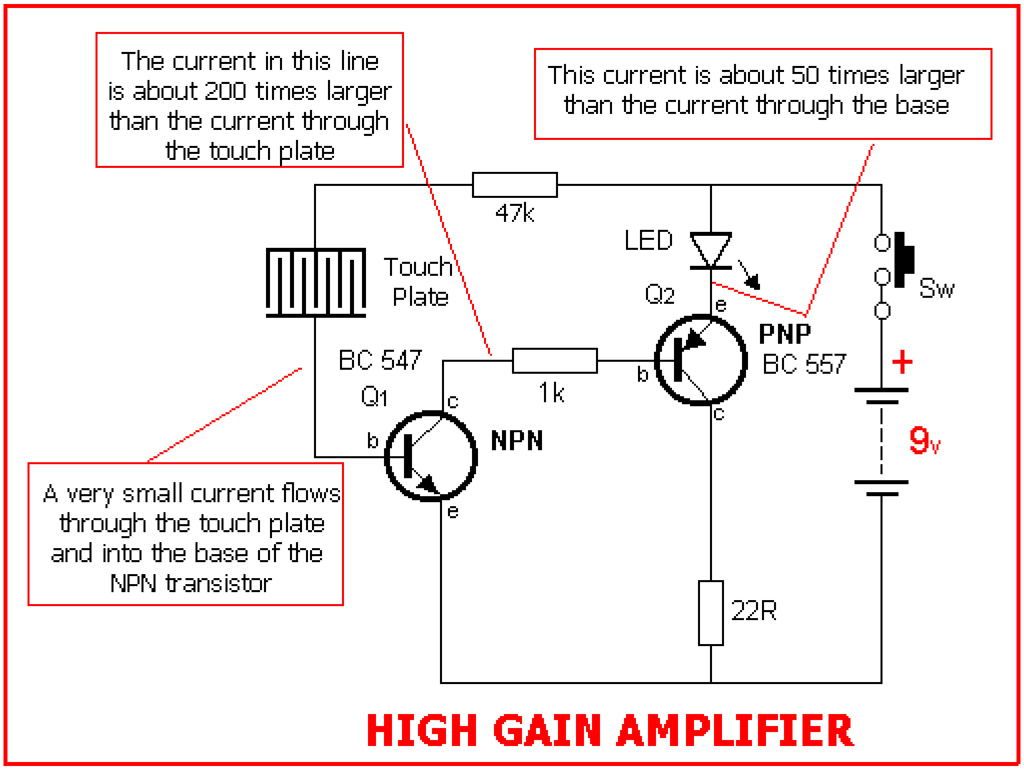
The actual gain of the PNP transistor is about 50 - 100 and depends on the current through the load.

In series with the emitter-collector leads of the PNP transistor is a LED and 22R resistor and the current that flows through this circuit causes the LED to illuminate.

PARTS LIST:

1 - 22R resistor (red-red-black-gold)
1 - 1k resistor (brown-black-red-gold)
1 - 47k resistor (yellow-purple-orange-gold)
1 - NPN transistor - BC 547
1 - PNP transistor - BC 557
1 - 5mm red LED
1 - slide switch
1 - 9v battery
1 - 9v battery snap
1 - touch plate
2 - 10cm wires for connecting touch plate

1 - "5-PROJECTS" PC board



CONSTRUCTION

The components for the **High Gain Amplifier** are fitted to the first section of the board. Refer to the diagrams to see where the parts go.

Three components are not fitted to this section for this project. They are: 100k, 10n and 10u electrolytic. These are fitted in the second project.

Pick out the components listed in the parts list and lay them on the work-bench. Now you can start assembly. Tick each step as you do it:

( ) Bend the leads of the 47k resistor to 90° and push them down the holes identified by the 47k symbol. Hold the resistor against the board with a finger while soldering so that it stays against the board after soldering. Resistors can be fitted either way around as they are not polarity sensitive devices.

( ) Fit the 1k resistor in the same way.

( ) Fit the 22R resistor.

( ) Fit the red LED so that the longer lead goes down the hole near the edge of the board. The short lead is the cathode and is identified on the board by the line on the symbol.

( ) Fit the NPN transistor so that the C, B and E leads fit down the correct holes. Refer to the large diagrams corresponding to the type of transistor you are using. Push the transistor down so that it is 3mm above the board. Don't fit it any closer otherwise the heat from the soldering operation will overheat the device.

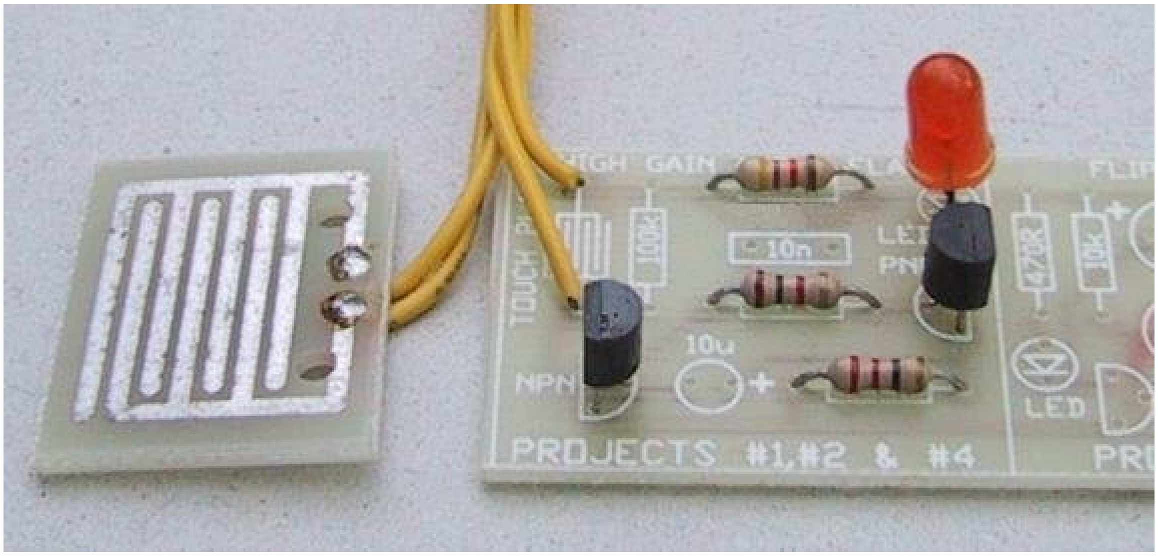
( ) Fit the PNP transistor in the same way.

( ) Cut the hook-up wire into 4 equal lengths and strip the insulation off each end for a distance of 3mm (3/8") and tin the ends with solder. Fit two of the leads to the holes on the PC board marked "Touch Plate" and solder them in position. Solder the other ends to the touch plate. Keep the other two leads for the speaker in project 5.

( ) Solder the slide switch to the board and paint the ON end with "white-out" then red nail polish to indicate the "ON" position.

( ) Solder the battery snap to the holes marked "+" (red lead) and "-" (black lead).

( ) Fit the battery to the snap and the project is complete.



Touch the Touch Plate lightly and the LED illuminates.

TESTING

Switch the project on and place your finger on the Touch Plate. As you press harder, the LED will illuminate brighter. This is the function of the circuit and it is working correctly.

You can determine the conductivity of various liquids by immersing the plate in the liquid and watching the LED illuminate.

You will find some liquids do not conduct electricity at all. Use some clean tap water and add a small amount of salt. Notice how the conductivity increases, even with the smallest amount of salt.

IF THE CIRCUIT DOESN'T WORK

If the circuit doesn't work as described in the notes, you will have a little bit of investigating to do.

Think yourself lucky if the circuit doesn't work as you will now begin to learn to trouble-shoot.

The only way to really learn electronics is to fix a faulty project. The problem at the moment is you are only a beginner and we have not covered any of the equipment need to test a circuit, such as a multimeter or Cathode Ray Oscilloscope (CRO).

The only thing you can do at this stage is go over the project and check each component against the parts list and visually compare the project you have built against the layout diagram.

Here are 10 of the most common faults, go through each one and make sure you have not made a simple mistake.

THE 10 MOST COMMON FAULTS:

1. Mixing up the resistors and fitting the wrong value(s) to the board.

2. Forgetting to fit a component.

3. Failing to solder one of the leads of a component.

4. Poor soldering or creating a dry joint.

5. Fitting a transistor around the wrong way.

6. Fitting the wrong type of transistor or mixing up the transistors.

7. Fitting the LED around the wrong way.

8. Forgetting to add leads to the touch plate.

9. Using a flat battery

10. Faulty leads to the battery or faulty switch contacts.

If you have not located the fault at this stage, it will be best to get someone with electronics knowledge to go over the project and let you know where you went wrong.

QUESTIONS

1. When you press harder on the Touch Plate, does the brightness of the LED increase?

2. Immerse the plate in pure distilled water. Does the LED illuminate?

3. Immerse the plate in tap water. Does the LED illuminate.

4. Add a few grains of salt to the distilled water and stir until dissolved. Test the water with the plate. Does the LED illuminate?

5. Immerse the plate in tea, coffee, cola, lemonade, lighter fluid, kerosene, turps, and state if the fluids are conductive or non-conductive.

ANSWERS

1. The brightness of the LED increases. 2. Pure water does not conduct current. 3. Some tap water will conduct and some does not conduct. Salts in the tap water allow current to flow and you can determine how pure your water is. 4. Salts in the water allow current to flow and turn ON the LED.

This completes the first project.

Page 15:

The second project on the board . . .

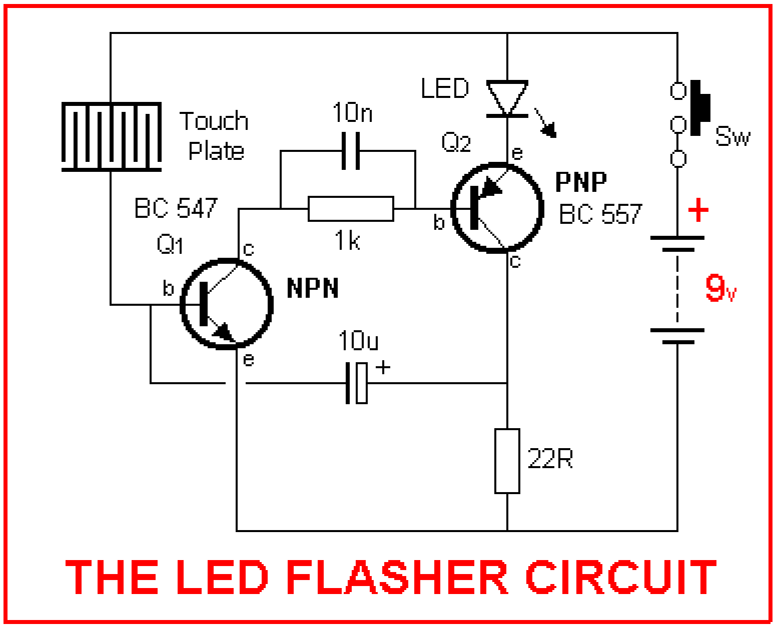
THE
LED FLASHER

Build your own LED FLASHER and learn how it works

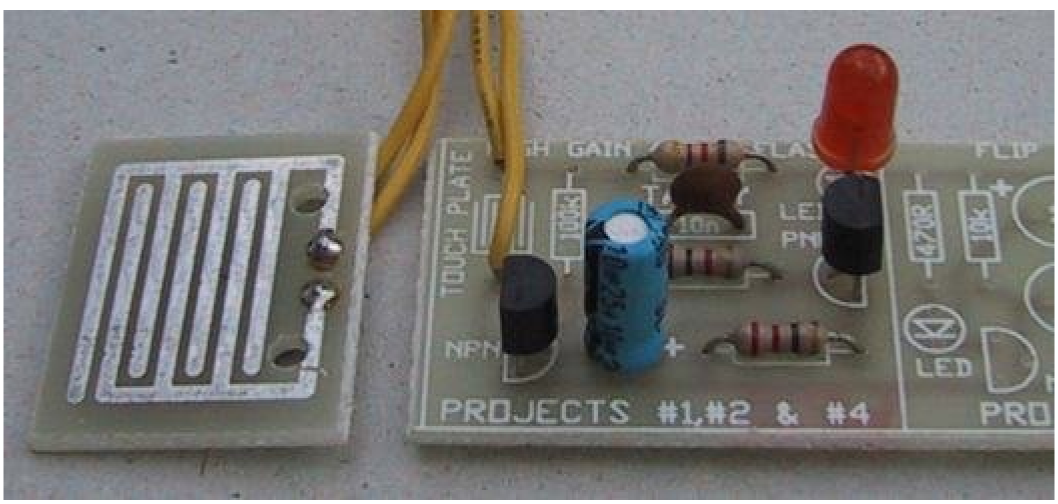
This is Project #2 on the PC board in "5-PROJECTS"

(you will also need a soldering iron, solder and side-cutters. These are available from your local electronics store)

In this project we flash a Light Emitting Diode (LED). The circuit is exactly the same as in project 1 with two additional components - a 10u electrolytic and a 10n capacitor. The 10u changes the operation of the circuit considerably and it's handy we covered the operation of the two transistor section in project 1 in so much detail so all we have to describe is the operation of the electrolytic.



The electrolytic is a feedback component and we will see how feedback alters the operation of a circuit.



Project 2 with Touch Plate fitted to PC board

CONSTRUCTION

( ) Fit the 10u electrolytic to the board as shown in the diagram with the positive lead going down the hole marked "+" and the negative lead down the hole next to it.

( ) Fit the 10n capacitor to the holes marked "10n".

Switch the circuit ON and touch the touch plate lightly. The LED will start to flash and as you press harder, the flash rate will increase.

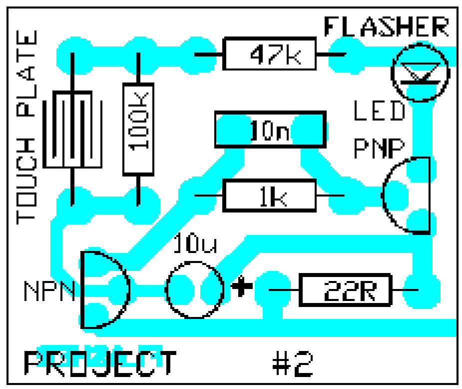
PARTS LIST

The HIGH GAIN AMPLIFIER must be built first

The extra parts for the LED Flasher:

1 - 100k resistor (brown-black-yellow-gold)
1 - 10n ceramic capacitor
1 - 10u electrolytic

We have already covered the operation of the two transistors and shown how they create a very high gain amplifier. We also explained how the current through the touch plate is amplified thousands of times by the two transistors and the result is sufficient to turn ON the LED.



Enlarged view of overlay showing where the parts are placed

The addition of the capacitor (the electrolytic comes under the broad heading of capacitors, along with greencap, ceramic, monoblock, polyester, styro, mica and others) turns the circuit ON for a very short period of time then off again, and the cycle repeats.

The LED is actually ON for only a very short period of time and your eyes extend the time considerably. This is one of the tricks used in electronics to save energy. Because it is ON for such a short time, the average current taken by the circuit is very small as it only draws current from the battery in very short bursts.

The only thing we will be describing in this project is the function of the 10u electrolytic.

HOW THE CIRCUIT WORKS

When the battery is connected, both the transistors are off. When you touch the touch plate, current flows through your finger to charge the 10u electrolytic. The 22R and 47k complete the charge path.

When the voltage on the base of Q1 rises to about .6v, the transistor turns ON and its collector-emitter resistance drops. This resistance is in series with a 1k resistor and they form the base-bias resistor for the PNP transistor. You will notice the PNP transistor and its base-bias resistor (the 1k and collector-emitter resistance of Q1) are inverse to the layout of the NPN transistor, so simply think "up-side-down" and you will understand the PNP version. Current passes through the Light Emitting Diode in the emitter of Q2 and it illuminates.

The current also flows through the 22R resistor and when current flows through a resistor, a voltage is developed across it. This voltage appears on the negative lead of the electrolytic and the electro is "raised up." The positive lead is also raised up by the

same amount and the energy that was put into the electrolytic at the beginning of the cycle flows into the base of Q1 to turn it on harder.

When the two transistors turn on harder the brightness of the LED increases. The voltage across the 22R increases and the electrolytic is raised even higher. This process continues to run around the circuit until both transistors are fully turned on and the electrolytic begins to charge in the forward direction via the base of Q1, the collector-emitter leads of Q2 and the LED. This produces the ON time for the LED and as we mentioned in the section on capacitors, the initial charging current for a capacitor is high and it gradually tapers off as the electro becomes charged. This is what happens in this case and when the capacitor is nearly fully charged, the charging current reduces to a point where Q1 is not turned on as much.

This causes Q2 to turn off slightly and the voltage on the positive lead drops a small amount. The negative lead follows and as we learnt in the section on transistors, when the voltage on the base of a transistor falls below .6v, the transistor does not turn on at all.

At this stage in the cycle Q1 turns off more and causes Q2 to turn off also.

A few more decrements and both transistors are fully turned off.

This causes the positive lead of the electrolytic to drop to the level of the negative rail.

The amazing part in this portion of the cycle is the electrolytic is fully charged and since the positive lead drops by about 7v, the negative lead falls by an equivalent amount and so the base of the first transistor sees a negative voltage (-7v!) that keeps it fully turned off.

The charge on the electrolytic is gradually neutralised by current flowing through the touch plate and when all the charge is neutralised, the electrolytic begins to get charged in the opposite direction by the same current. The time this takes produces the OFF time for the LED.

The OFF time is considerably longer than the ON time because the current through the touch plate is much smaller than the current through the transistor and LED when charging the electro.

The electrolytic needs to charge to about .6v before the cycle starts again.

You will notice the electrolytic has been placed in the circuit "around the wrong way," with the positive lead only 22R away from the negative rail. When the cycle begins, the electro gets charged in the opposite direction to about .6v but later in the cycle it gets charged in the forward direction to about 7v. The electro will accept a small reverse charge without being damaged, provided most of the charging is done in the forward direction.

The operation of the circuit is really quite complex and don't be surprised if you don't understand it fully. Future e-books will go over these building blocks again and bring everything into focus.

EXPERIMENTING

The object of these projects is to carry out as much individual experimenting as you can before going on to the next project.

Experiment with different pressures on the touch plate and try other substances such as a slice of fruit or vegetable to see how the conductivity of the each compares with your finger.

You can also try some of the liquids mentioned in Project 1, Question 5, to see how they affect the flash rate.

Later, in Project 5 you will be able to test the liquids again with the Siren Circuit and see how much easier it is to work with an audio output to determine the variations in frequency, rather than watching a changing flash rate.

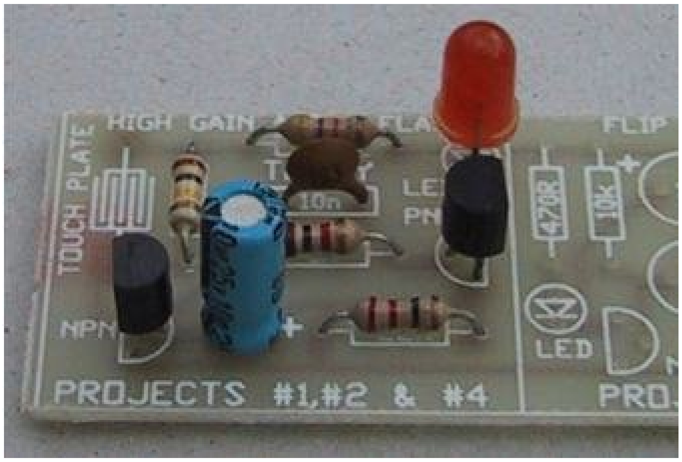
FITTING THE 100k RESISTOR

The touch plate will be required for Project 5 and once you have carried out all the experiments for this project, it can be removed and replaced with a 100k resistor.

( ) Remove the Touch Plate and leads from the PC board

( ) Fit the 100k (brown-black-yellow-gold) resistor near the Touch Plate symbol.

This will create a fixed flash rate of about one flash per second (1Hz).



Project 2 with 100k resistor fitted to the board

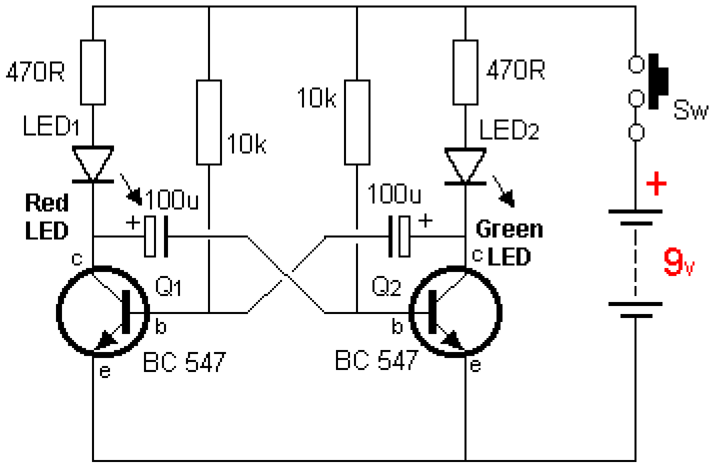
This completes the second project.

The third project on the board . . .

THE
FLIP FLOP

Build your own Flip Flop circuit and learn how it works

This is Project #3 on the PC board in "5-PROJECTS"



THE FLIP FLOP CIRCUIT

In this project we examine one of the most valuable circuits to be invented - **the flip flop**. Originally it was designed with VALVES, along with its simpler version (without the two capacitors - called a **bi-stable Multivibrator**), it was realised it could store a "bit" of information. The bi-stable Multivibrator circuit required an input pulse to the left side of the circuit and the load (say a globe) stayed ON when the signal was removed. A pulse to the other side of the circuit turned the globe OFF. This was the first time an electronic circuit had stored a "piece of information." This was the beginning of the COMPUTER AGE.
When you realise each letter on this page requires 8 circuits like this to store the "bits" you can see how little each "storage element" can hold. That's why you need millions of cells similar to the Flip Flop circuit to hold data for even the simplest application.

RECOGNISING A FLIP FLOP CIRCUIT

The Flip Flop is a symmetrical arrangement using two transistors with cross-coupling. Each transistor has a base bias resistor (10k in our case) and a LED with 470R resistor in the collector lead to form the collector load.

The circuit consists of two identical halves and is called a **Flip Flop** because one half is **ON** while the other half is **OFF**. The ON half is keeping the OFF half OFF but it cannot keep it off indefinitely and gradually the OFF half turns ON via the 10k base-bias resistor. This drives the ON side OFF and the circuit changes state. In other words it flips over. The same events occur in the other half of the cycle and the circuit eventually flops back again.

This sounds very complicated but in reality the circuit is quite simple in operation as one half is exactly the same as the other and there's only 5 components in each half.

THE FLIP FLOP IS A FREE-RUNNING MULTIVIBRATOR

The circuit is self-starting and only one LED is on at a time. It is a free-running multivibrator (this means it does not stop) and we will describe its operation in a non-technical way. A free-running multivibrator is also called an **astable multivibrator** (meaning is has no stable states) and that is why it flips from one state to the other continuously.

The standard way to draw this type of multivibrator is to show the two capacitors crossing at the centre of the circuit, this also gives the circuit symmetry and makes it easy to recognise.

The other way to identify an astable multivibrator is knowing that it has two capacitors. (The **monostable** multivibrator has **one capacitor** and the **bistable** multivibrator has **no capacitors**.)

In simple terms, the astable [pronounced (h)ay-stable] multivibrator has two states. When one transistor is turned on it operates (supplies current to) a LED (or other device) in its output line and at the same time keeps the other transistor off. But it cannot keep the other off forever and eventually the other transistor begins to turn on. When it does,

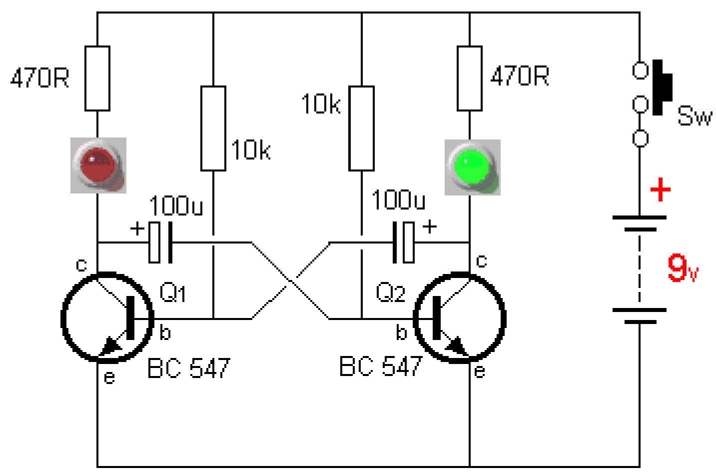
the action turns the first transistor off slightly and a change-over begins to occur. This produces the flip action.
After a short period of time the other half of the circuit cannot be kept off and the whole arrangement flops back to the first state.

The components that determine the frequency are the electrolytics and two base-bias resistors. If these values are changed, the frequency will alter.
For instance, if the electrolytics are reduced in value, the frequency will increase and if the resistors are decreased, the frequency will increase.

If you increase the frequency of this circuit to more than 20 cycles per second, it will appear as if both LEDs are on at the same time. But the fact is the circuit will be operating faster than your eye can see and that's why we have chosen large values of capacitance to slow it down.

When the electrolytics and resistors are made equal value (as in our case), each LED flashes for the same length of time. This is called an equal mark-space ratio: (50%:50%).
This means the flip time is the same as the flop time.
Theses components can be changed to any ratio, to give different effects.

THE FLIP FLOP IN ACTION



THE FLIP FLOP CIRCUIT IN ACTION

The animation above shows the Flip Flop circuit in action with the red and green LEDs.

CONSTRUCTION

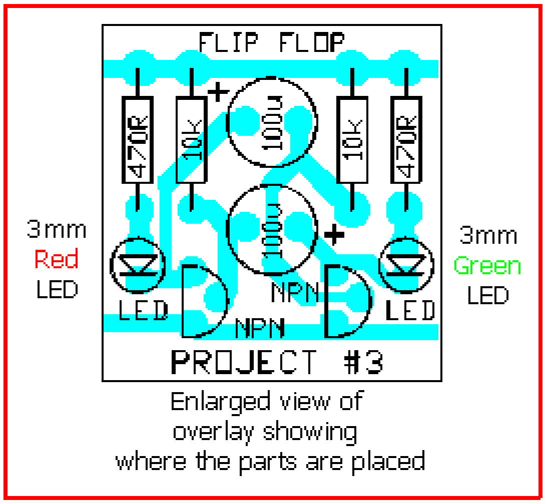
As each step of the construction is completed, the ( ) should be ticked.
( ) The four resistors fit flat against the board. To make them sit neatly, bend the leads to 90° with a sharp bend and push them up to the board before soldering.

( ) The two 100u electrolytics are next. The positive hole is marked on the board for each electro. This is the longer lead. The negative lead is marked on the component with a black stripe.

( ) Fit the two NPN transistors. We have used BC 547 but any general-purpose NPN low-power transistor will be suitable. They are pushed to the board so that the transistor matches the "D" outline on the board. If the transistors supplied in the kit are different, a modification sheet will come with the kit.

( ) The red and green LEDs can be fitted to either position on the board. The short lead is cathode (k) and this is the bar on the symbol.

( ) The project is now ready to turn on.



The Flip Flop components added to the board

HOW THE CIRCUIT WORKS

We have already explained how the circuit works already but there are a few terms that can be gone over again to explain the condition when a transistor is **conducting** and when it is **non-conducting** (turned off).
We can also talk about the electrolytics, as they are experiencing a voltage change on their leads that is not obvious at first glance.
We can also mention that a conducting transistor is equivalent to a very low value resistor (we are talking about the resistance between the collector-emitter leads). In fact we can think of it more accurately as a very low voltage drop, in the order of about 0.35v.

A transistor that is OFF is called CUT-OFF and one that is fully turned ON is called BOTTOMED or SATURATED.

These are the two states for the transistors in the Flip Flop circuit. One transistor is CUT OFF while the other is SATURATED.

With these facts in mind we can again go through how the circuit works. When the power is applied, the slight difference in characteristics between the two transistors and electrolytics causes one transistor to turn on faster than the other. Suppose Q1 turns on faster via
the uncharged 100u electrolytic C1, LED2 and the 470R resistor.

The voltage on the collector of Q1 will drop to about 0.35v and LED1 will light up. The positive lead of capacitor C2 will have 0.35v on it and this voltage will also be on the base
of Q2. Transistor Q2 will be turned off by this action but LED2 will come on for a short time while C1 charges.
C2 begins to charge in the reverse direction (electrolytics can do this provided the voltage is not too high) and as the voltage rises above .6v, Q2 begins to turn on. This lowers the voltage on its collector and begins to turn on LED2.

The positive end of C1 is also connected to the collector and as the voltage drops, this effect is transferred to the base of Q1 via C1. This action begins to turn off Q1 and its

collector voltage rises.
Since C2 is connected to this point, the base of Q2 will see a rising voltage and it will turn on harder. In a very short time the two transistors have changed state.
There's a little more concerning C1.

An electrolytic can be considered to be a rechargeable battery and when C1 is charged at the beginning of the cycle, it will have about 5v across it (for a 9v supply).

If we change this to a 5v rechargeable battery the explanation will be easier. The positive terminal of the battery will be connected to the collector of Q2 and when the transistor turns ON, the collector will be .35 above the negative rail. (the zero rail).

This means the negative terminal of the battery will be 4.85v BELOW the zero rail. In other words the base of Q1 will see a negative voltage of 4.85v.

And this is exactly what happens. The energy in the electrolytic will now be removed by the 10k resistor and after a short time the base will see a positive voltage of .6v and Q1 will begin to turn on and change the state of the circuit.

This is how the delay is created for each of the cycles.

Before we leave the multivibrator there's an important concept that should be explained.

Since each transistor is either ON or OFF, the circuit is classified as DIGITAL, since it has only two states and the time to change from one state to the other is so fast that we do not take it into account.

If we take the collector of one of the transistors, say Q1, it will be either HIGH or LOW and never part- way between.
These digital states will be very important later in our course, when we connect transistors to integrated circuits.

Integrated circuits are digital devices with inputs that only accept either HIGHs or LOWs. The transition time between these two states must be very quick to prevent noise getting in. If noise were to get in, the circuit would not work. Many IC's are counting devices and noise will cause them to count at maximum speed. Others will create excessive noise if the input line is at about mid-rail voltage. It takes a small period of time for the chip to start to produce counting
or noise and if the transition is fast enough, it does not get the opportunity to start-up.

The astable multivibrator is also called an oscillator and when it is connected to an IC it will provide pulses called clock pulses. These clock pulses enable the IC to count or perform other functions such as division etc.

The flip flop is also called a square wave oscillator and either the same circuit or a similar circuit is now available in an IC to produce clock pulses.

QUESTIONS

1. What type of multivibrator is presented in this project?

2. Name the two other types of multivibrator.

3. How many capacitors does a monostable multivibrator have?

4. Give another name for a fully conducting transistor.

5. What is the value of base voltage when a transistor begins to turn ON?

6. When a transistor is fully conducting, what is the voltage between collector-emitter?

7. What is another name for a transistor that is switched OFF?

8. What is another name for an astable multivibrator?

9. If the electrolytics in the Flip Flop are replaced with 47u, what will happen to the

frequency of the circuit?

10. Can both LEDs be ON at the same time?

ANSWERS:

1. Astable multivibrator.

2. Monostable multivibrator, Bistable multivibrator.

3. One.

4. Saturated, bottomed, output 0, output LOW.

5. .6v

6. .35v

7. Cutoff, output HIGH, Output 1.

8. flip-flop

9. It will increase in frequency.

10. No. Only one LED can be illuminated at a time.

A great project to teach . . .

FIBRE OPTICS

This project uses the "Flip Flop" circuit to create a flashing fibre optic sign

This is Project #4 on the PC board in "5-PROJECTS"

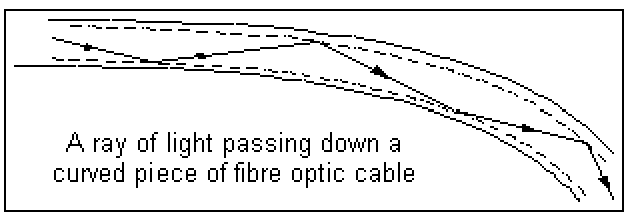
The display section of this project is built on a separate PC board contained in the 5 PROJECTS kit. It has a matrix of very fine holes, 7 holes by 10 holes to take plastic optical fibre, also contained in the kit.
The electronics to drive the display board is the Flip Flop project built in Project #3 or the single flashing LED from Project #2.
It all depends if you want a single flashing effect or a dual flashing effect.
The PC board is shown in the photo below:

The Fibre Optic project uses the Flip Flop circuit created in Project #2 or #3

Fibre Optics is the communication medium of the future and its presence will grow with the enormous demand in personal communications. The advantage of optical fibre is its lightness, small size and it is cheaper than copper. But the biggest advantage is the bandwidth it offers. A single fibre can carry many television channels at the same time, all with perfect digital clarity.

The biggest demand will come from home entertainment; for interactive television, video phone, and global computer networking. The explosion will be likened to the growth of the home computer industry, some 20 years ago. The Information Superhighway as they call it, will be here very soon and the only way to meet the demand for information to every household will be via fibre optic cable.
Basically the cable will take the place of the telephone line and allow television, video and computer channels to enter the home.
In this project we create a very simple fibre optic channel to convey light from a source to a destination.

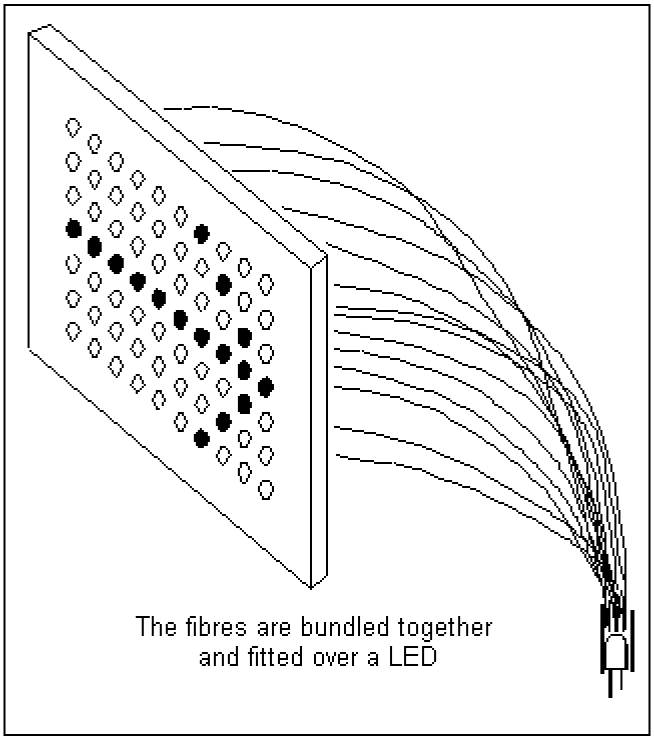
The type of fibre we are using looks like ordinary fishing line but fishing line will not work. Fibre optic cable is very special in its construction and the diagram below shows how it works. It is a miniature light guide.



It is not simply a length of plastic line but it has a very thin coating over a clear plastic polymer so that the light entering one end of the fibre will appear at the other.

MAKING A FIBRE OPTIC SIGN

The "5 PROJECTS" kit comes with a length of fibre optic cable and a miniature PC board so you can make a **FIBRE OPTIC SIGN** suitable for a model train layout. As shown in the diagram, the fibres are pushed into a drinking straw or plastic tubing so the light from a LED can can be used to illuminate the sign.

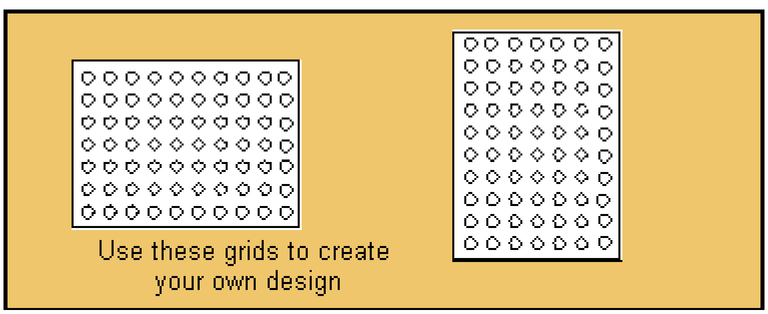


The reason why the light passes down the fibre and doesn't disappear out the sides, is due to a phenomenon called total internal reflection.
This is where the light hits the side of the cable and is reflected back into the cable with very little of it escaping to the outside.

The diagram shows one ray of light and the path it takes as it passes down the fibre. The cladding on the outside of the fibre need only be very thin and it must have a lower refractive index than the main fibre to create internal reflection.

The light hits the side of the cable many times as it passes down the fibre and a very small amount is lost each time it is reflected. This is why the cable has a limit of about 10 metres before the light is reduced to a level that makes it unusable.

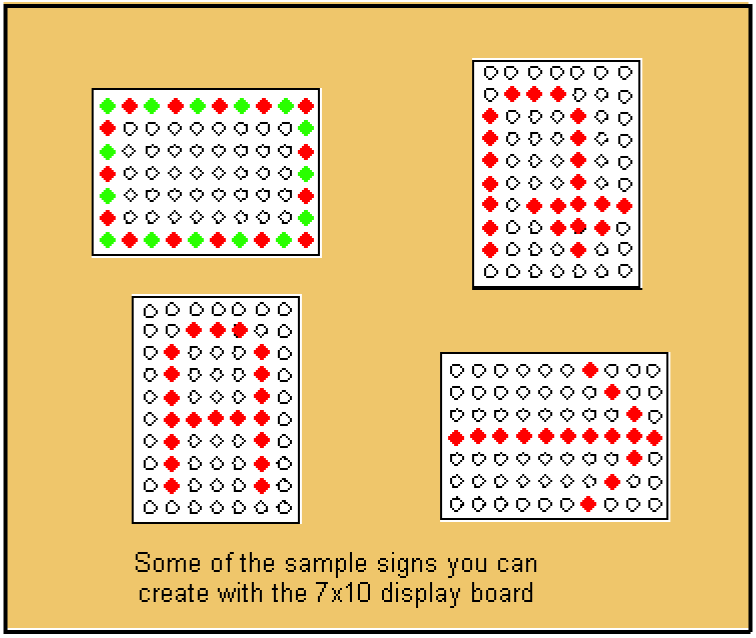
The fibre optic cable we have supplied in the kit is called "plastic." You can also purchase much better quality cable manufactured from glass but it is extremely brittle and could not be used in this project without breaking.



PARTS LIST:
1 - Flip Flop project #3
1 - 7x10 matrix board (0.7mm holes)
1 - 3m (10ft) plastic fibre optic cable
1 - drinking straw to put over LED

Optical fibre produces a very small point of light and is ideal for making a miniature sign for a model layout etc.

The board with 7x10 matrix of holes provided in the kit will allow you to make almost any type of sign and you can create your own designs on the blank layouts provided and transfer them to the board.



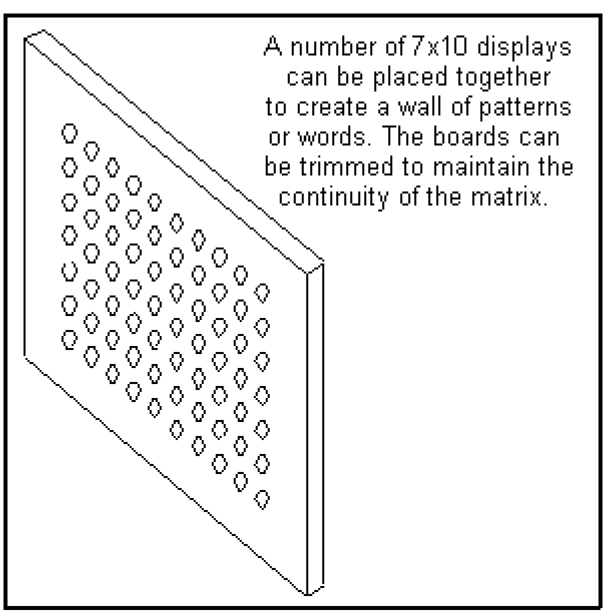
This project allows a wide range of designing and experimenting. The 7x10 matrix can be turned around to a 10x7 arrangement and the sample diagrams give you some idea of the patterns and designs that can be created.

You can take the ends of the fibres to a single LED or any of the three LEDs on the PC board.

You can also change the LED on the LED Flasher to a HIGH BRIGHT orange LED to create a 3 colour sign.

You will really appreciate the effectiveness of this project if you have a model railway as the most difficult thing to achieve on a layout is a realistic sign to match the size of the surroundings.

You can create blinking lights around a shop window by running each consecutive fibre to a different LED.



The diagram above shows how the fibres are placed through the holes in the board and bundled together to fit into a piece of plastic drinking straw. You can make one, two or three bundles, depending on how complex and colourful you want the sign to be. These bundles then fit over the LEDs on the PC board. Since they flash at different rates and are of different colours, the effect you will create will be quite interesting.

To keep the fibres in place on the matrix board, the ends are lightly touched with the barrel of a soldering iron. This will make them swell and prevent them pulling back through the holes. You can then hold the fibres in place with a small amount of glue at the back of the sign but make sure the glue does not melt them!
To get the best light transfer between the LED and the ends of the fibres, they should all be cut to the same length and the top of the LED can be flattened and polished.

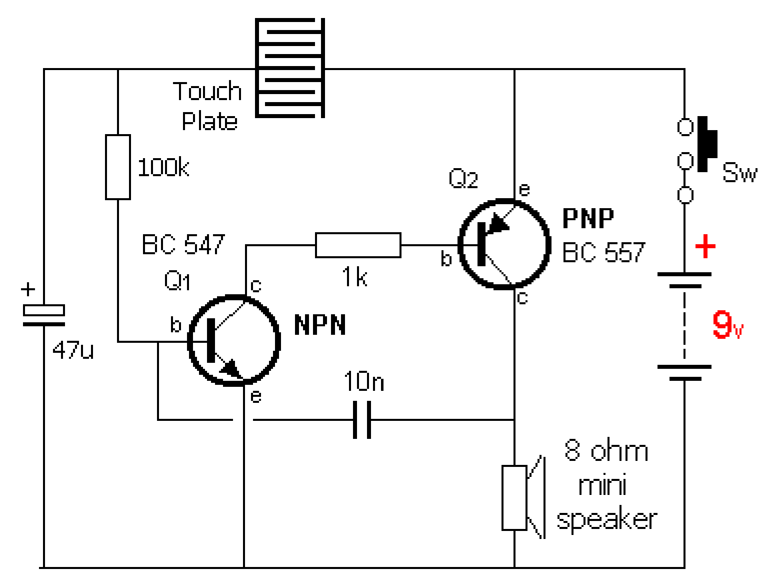
The 7x10 pattern can be used to create letters or words for a miniature display. In place of the LEDs, a bright lamp can be used to create an effect that can be seen in daylight.

SIMPLE SIREN

Build your own Simple Siren and learn how it works

This is Project #5 on the PC board in "5-PROJECTS"

This project is built on the third section of the PC board, identified by "SIREN" and "Project 5." You will notice the similarity between this circuit and the LED FLASHER circuit from project 2. The only differences are the LED has been removed and the 22R resistor has been replaced by a mini speaker.



SIREN CIRCUIT

The 10u has also been replaced with a smaller value of capacitance (10n) and this makes the circuit operate at a much higher frequency. The result is a tone from the speaker. (If you connected the speaker to the LED Flasher circuit you would get a "click - click - click"

at 2 clicks per second.

This SIMPLE SIREN circuit uses components we have covered in the front of this book and up to now you have seen how a varying current on the base of the first transistor affects the flash rate of the circuit. Now you will HEAR how the varying current alters the frequency at
which the circuit operates.

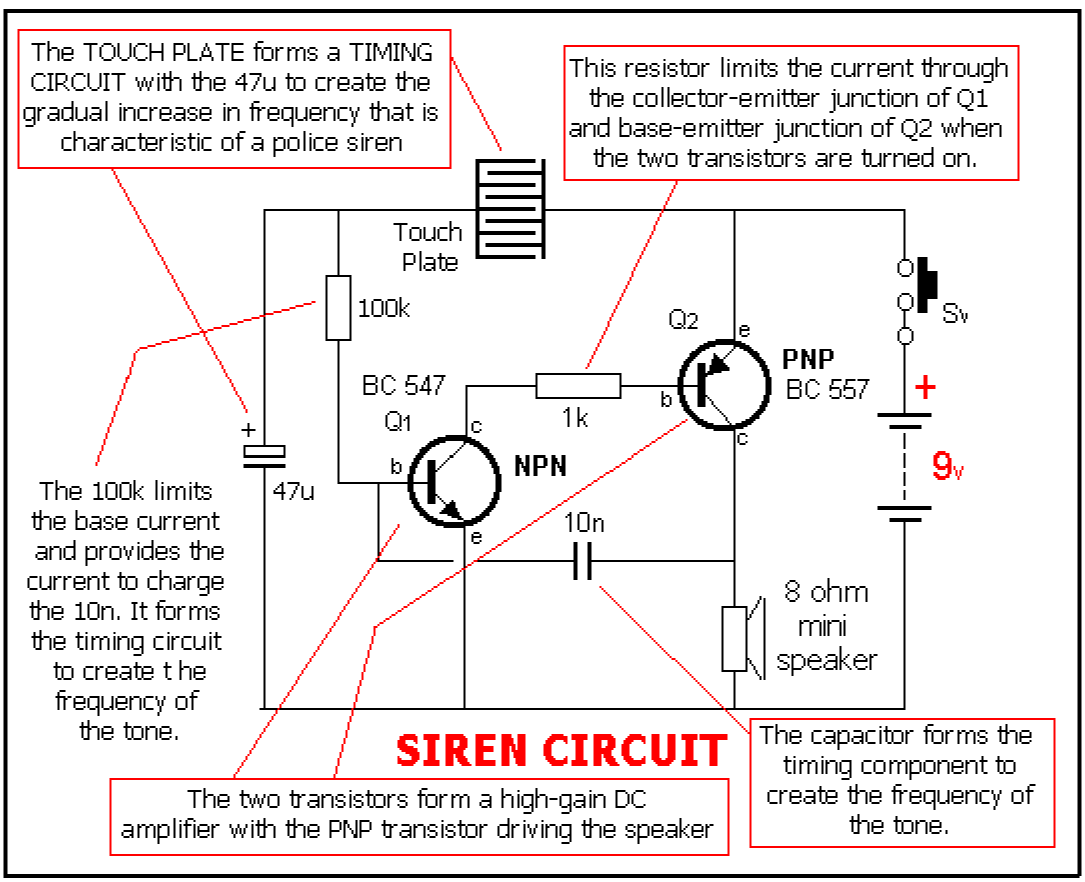
PARTS LIST

1 - 1k resistor (brown-black-red-gold)
1 - 100k resistor (brown-black-yellow-gold)
1 - 10n greencap or ceramic
1 - 47u 16v electrolytic
1 - BC 547 NPN transistor
1 - BC 557 PNP transistor
1 - 8R speaker
1 - touch plate - (from project 2)
1 - 20cm hook-up wire for speaker
1 - "5-PROJECTS" PC Board

HOW THE CIRCUIT WORKS

There are many ways to explain how a circuit works and we have presented three different approaches in this course - the voltage approach, the current approach and the resistance approach. Sometimes we have combined all three.

In this final project we will explain how the circuit works using the resistance approach. We start with the touch plate. When the touch plate is touched, the 47u electrolytic gradually charges via the resistance of the plate. In the notes we have explained how the touch plate works, with its resistance varying according to the pressure of your finger.
The base of Q1 sees the voltage on the electrolytic and when it is about .6v, the transistor starts to turn on.



Since Q1 is directly coupled to the second transistor, Q2 turns on too. When Q2 turns on, the resistance between its collector and emitter reduces and allows current to flow. This causes current to flow in the voice coil of the speaker and pulls the cone towards the magnet.

This is the first half of the cycle for the speaker.
Also connected to the collector of the PNP transistor is one end of a 10n capacitor and when one lead of the capacitor rises, the other side rises too. (This is because it is uncharged at the moment). This has the effect of turning on both Q1 and Q2 even harder. This action runs around the circuit until both transistors are turned on fully.

At this point the 10n capacitor begins to charge via the base-emitter junction of Q1 and the collector-emitter junction of Q2. When the capacitor becomes nearly charged, the charging current reduces and it cannot keep Q1 turned on as much and it begins to turn off slightly.

This begins to turn off Q2 and the voltage on the collector of Q2 falls. The 10n capacitor is connected to this and both ends begin to fall and turn off Q1. This action turns both transistors off and the voltage on the base of Q1 is below the negative rail (as explained in Project 2).

Current through the voice coil of the speaker ceases and the cone is released. This completes the cycle for the speaker and it's the action of pulling the cone towards the magnet and releasing it that produces the tone.

The charge on the capacitor is now cancelled by the current from the 100k resistor and it begins to charge in the opposite direction so that the voltage on the base of Q1 rises to .6v. At this point the NPN transistor turns on again and the cycle repeats.

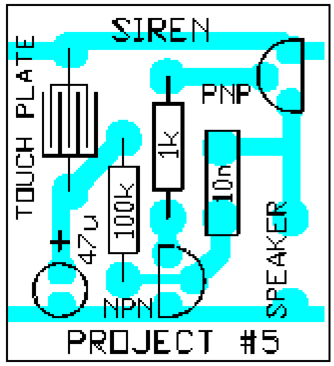
If the touch plate is kept touched, the tone from the circuit gradually rises as the time taken to charge the capacitor at the end of the cycle will be shortened. This is due to a higher voltage being present on the electrolytic and thus a higher current will flow through the
100k resistor to charge the capacitor faster.

Most of the explanations of how the circuits work have opened up more questions than they answered. This is only a commencement book and future books will elaborate on the operation of the circuits in more detail. Even if you have only learnt the resistor colour code and got the projects to work, you will have achieved all this book has intended to get across.

Furthermore, if you like what you have learnt, electronics will be buzz and a very rewarding hobby. Look out for the next books in the series.

ASSEMBLY

All the components fit on the section of the PC board marked "SIREN." The two resistors lay flat on the board and the other components are pushed up until they are about 3mm (3/16") from the board. Use the layout diagram on this page to see where they go and how they fit. Don't forget to hold each part as you solder it to make sure it doesn't get too hot.



Enlarged view of overlay, showing the location of the components

Now for the assembly.

Collect the parts and lay them on the work bench.
You are now ready to start. Mark off each step as you do it.
( ) Bend the leads of the 1k resistor to 90° and push them through the holes identified by the 1k symbol on the board and hold the resistor while soldering it. Cut the ends of the wires with a sharp pair of side cutters making sure you do not cut any of the solder joint, as this may damage it.

( ) Repeat with the 100k resistor.

( ) Fit the 10n capacitor by pushing the leads through the holes until the body of the capacitor is almost touching the board. Solder the leads quickly so that the component does not get too hot. Cut off the leads neatly.

( ) Fit the 47u electrolytic with the negative lead close to the edge of the board and the positive lead down the hole marked with a "+."

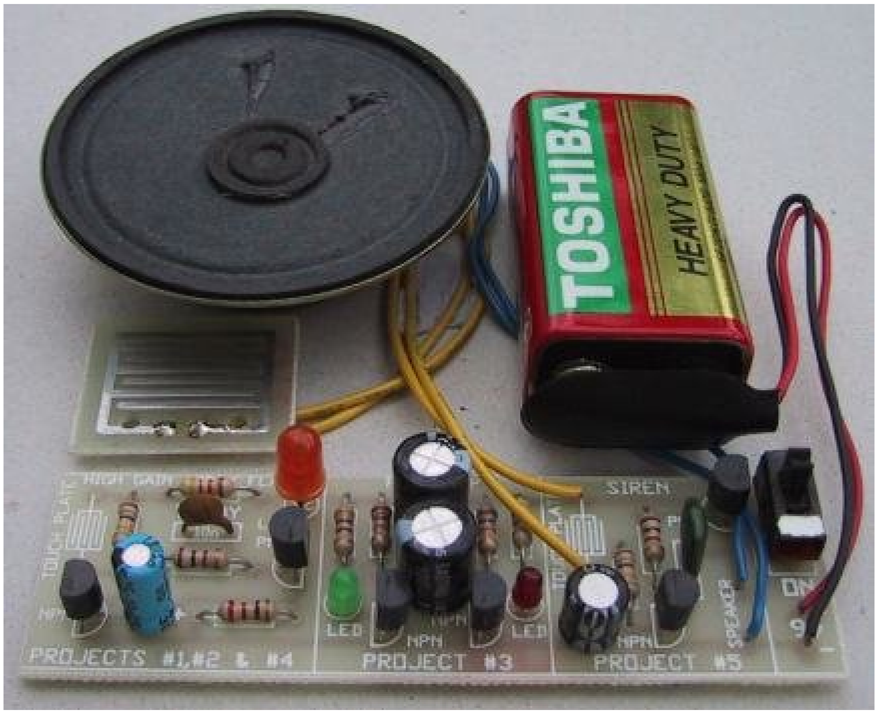
( ) Fit the PNP transistor at the position marked on the board with a "D" symbol, making sure the leads are correct for the transistor you are fitting.

( ) Fit the NPN transistor in the same way.

( ) Connect the touch plate to the holes marked on the board via the two wires attached to it, (you may have to remove it from the other section of the board.)

( ) Fit the speaker wires to the speaker and solder the other ends to the board.

The project is now complete.
Slide the power switch on and the touch the touch plate. After a short while the siren will start up. Keep your finger on the touch plate and the tone will increase. You can regulate the tone by pressing lightly or with more force.



The Siren components fitted to the board.
Touch the Touch-Plate to increase the Siren tone
release to decrease tone.

IF THE CIRCUIT DOESN'T WORK

If the circuit doesn't work, you should go over the construction notes again, making sure you have not left anything off the board. Look at the solder side of the board and make sure no joints have been left unsoldered.

If the other projects are flashing when the power is switched on, the battery will be ok. This circuit will work down to a voltage of 3-4v, so it is not voltage critical.

Look at the speaker to make sure the leads are soldered correctly. The other major cause of a mistake is the transistors. Make sure they are the correct types for both the NPN and PNP positions and make sure they have been fitted correctly.
Get someone else to check this for you as it is difficult to check your own work.
If you have held the transistors while soldering, they will not be damaged, but if you had to let go, they could be damaged.

Buy two more as "spare parts" and fit them to the board.
In later pages we will show how to test the circuit using a multimeter and other test equipment but we have not covered these yet and the only thing you can do is visually inspect the board for correct parts placement and make sure the soldering is neat.

If you have made a mess of your PC board, it would be a cheap price to buy another board (or book), get another kit of components and start again.
This time you will make a much neater job and learn a lot in the process.
You really have to feel you have been successful with this e-book before you should go on to the next in the series.

WHAT HAVE YOU LEARNT?

These are the areas we have covered in this e-book: Tick those you have understood:
( ) Recognising components such as transistors, resistors, capacitors.
( ) Placing components correctly on a Printed circuit board.
( ) Soldering components neatly to a PC board.
( ) Holding components while soldering so that they do not get too hot.
( ) Understanding the concept of resistance - high resistance and low resistance.
( ) Understanding the concept that a capacitor stores energy - it "charges up."
( ) Understanding a speaker produces a tone by current flowing through
the voice coil then ceasing to flow and repeating the process to produce a tone.
( ) Understanding a LED produces coloured light when current flows through the special

type of crystal it is made of. The colours are: red, green, yellow, orange and blue.
( ) Understanding a transistor is an amplifying device with the
base as the input and the collector as the output.
( ) Understanding current flows through a circuit when it is switched on. In the siren circuit for example, there are a number of different current paths and a different value of current flows through each path.
You don't have to FULLY UNDERSTAND any of the concepts, just be aware that they exist and be prepared for further study in future pages.

THE END

This completes the 5 projects.
There is a lot to be learned from the circuits in this project as they are often used in our other projects.
You can experiment with the circuits to create different effects. By placing a different value resistor across those on the board, you will be able to see the effect of lowering the resistance.
Some of the capacitors can also be changed and the effect will be quite noticeable. This is a very good way to find out the effect of various components on the operation of the circuit.

TEST

We hope you enjoyed this e-book and learnt a lot about electronics.
To see how much you have gained, we have produced a final test.

You can do the test at any time. The best idea is to do it both before and after you complete the projects and compare the results.

You can look through these pages at any time to help with the answers as there is no such thing as "cheating."

There is nothing wrong with getting assistance with the answers as you are not expected to remember everything. Half the skill of being organised is knowing where to look for information.

That's why we have libraries.

Your raw score is not the one that matters. The score that has more meaning is the difference between your first attempt and your second, with the second attempt taken after you have finished the projects.

This will give you a comparative mark and will let you know how much you have learnt from the course.

If possible, it is best to take the second test a few days after completing the projects so that you get a result that reflects your long-term memory.

You see, you have two memories. A short-term memory and a long term memory.

The object of learning is to put information into your long term memory. Once it is there you never forget it.
To put something into your long term memory you quite often have to go over the details you wish to remember, a short time after they were initially learned.

When you do this, the information becomes strengthened.
This action puts it into a different section of your brain (called the long term memory section) into operation.
Some people have the ability to put information directly into long term recall while others cannot remember the people they meet, five minutes after being told their names!
Let's see how you score with recalling the facts from these projects.

Give yourself the marks shown for each question.

TEST:

1. When soldering, do you take the solder on the iron to the joint or apply the solder when the iron is close to the joint? (1 mark)

2. Solder for electronic work must have __________ in the centre to clean the joint while soldering. (1 mark)

3. Name the two sizes of solder we recommend: (2 marks)

4. Draw the symbol for each of these components:
(a) resistor

(b) capacitor

(c) electrolytic

(d) NPN transistor

(e) speaker

(f) two wires crossing, but not connected

(g) slide switch

(h) battery

(i) PNP transistor

(j) touch plate

(20 marks)

5. The Touch Plate is equivalent to a variable _______________ . (1 mark)

6. When you press firmly on the Touch Plate, the resistance between the tracks: increases/decreases? (1 mark)

7. When the resistance of the Touch Plate increases, does more current or less current flow through the terminals of the plate? (1 mark)

8. The two types of transistors we have used in these projects are: (2 marks)

9. Name the resistor we covered in the notes for biasing a transistor:

(a) ______________________ (1 mark)

10. LED stands for: (1 mark)

11. The shortest lead on a LED is: (1 mark)

12. What is the characteristic voltage that develops across a red LED when it is illuminated?
___________ (1 mark)

13. Give another name for Flip Flop: (1 mark)

14. Give the colour bands for these resistors:

(a) 10k

(b) 47k

(c) 22R

(d) 1k

(e) 330k

(10 marks)

15. What is the value of these resistors:

(a) red-red-black-gold

(b) yellow-purple-orange-gold

(c) brown-black-yellow-gold

(d) orange-orange-red-gold

(e) red-red-red-gold

(f) brown-black-green-gold

(12 marks)

16. Write the preferred notation for these values:

(a) 1,000 ohms

(b) 1,000,000 ohms

(c) 2,200 ohms

(d) 4,700,000 ohms

(e) 100,000 ohms

(5 marks)

17. Name 3 functions of a resistor:

(a) ______________________

(b) ______________________

(c) ______________________

(3 marks)

18. Resistors can be connected in parallel and _____________. (1 mark)

19. Does a resistor increase or reduce the current through a circuit? (1 mark)

20. Name three types of capacitor:

(a) ______________________

(b) ______________________

(c) ______________________

(3 marks)

21. What is another name for a free-running multivibrator? (1 mark)

22. What is the name given to a circuit with a resistor and capacitor in series? (1 mark)

23. Light passes through an optical fibre by a process called total internal __________________.

(2 marks)

24. From the following list, write the (a) amplifying device, (b) the energy storing component, (c) the current resisting component. (d) the energy supplying component and (e) the sound outputting device for project 5.

LED, battery, switch, speaker, transistor, resistor, capacitor.

(a)

(b)

(c)

(d)

(e)

(5 marks)

25. Name the three leads of a transistor:

(a) ___________________

(b) ___________________

(c) ___________________

(3 marks)

26. An NPN transistor is a mirror image of a __________ transistor. (1 mark)

27. The input lead of a transistor is:_______________________ (1 mark)

28. The output lead of a transistor is: ____________________ (1 mark)

29. Name the components with these values:

(a) 10n

(b) BC 557

(c) 100k

(d) 10u

(e) 9v

(f) 22R

(6 marks)

30. Explain how the speaker produces a tone. (2 marks)

31. Name the two components in a Timing circuit. (2 marks)

32. List 5 preferred resistor values: (5 marks)

Answers:

1. Apply the solder when the iron is close to the joint.

2. Rosin

3. 0.7mm and 1mm

4. See Symbols page

5. resistor

6. decreases

7. less

8. PNP and NPN

9. base-bias

10. Light Emitting Diode

11. Cathode (k)

12. about 1.7v

13. Multivibrator

14. (a) brown-black-orange

    (b) yellow-purple-orange

    (c) red-red-black

    (d) brown-black-red

    (e) orange-orange-yellow

15. (a) 22R (b) 47k (c) 100k (d) 3k3 (e) 2k2 (f) 1M

16. (a) 1k (b) 1M (c) 2k2 (d) 4M7 (e) 100k

17. (a) as a current limiter, (b) as a voltage divider, (c) as a time delay component

18. series

19. reduce

20. (a) air, (b) mica, (c) polyester (d) ceramic, (e) electrolytic (f) greencap (g) monoblock.

21. astable multivibrator

22. timing circuit or delay circuit

23. reflection

24. (a) transistor (b) capacitor (c) resistor (d) battery (e) speaker

25. (a) base (b) collector (c) emitter

26. PNP transistor

27. base

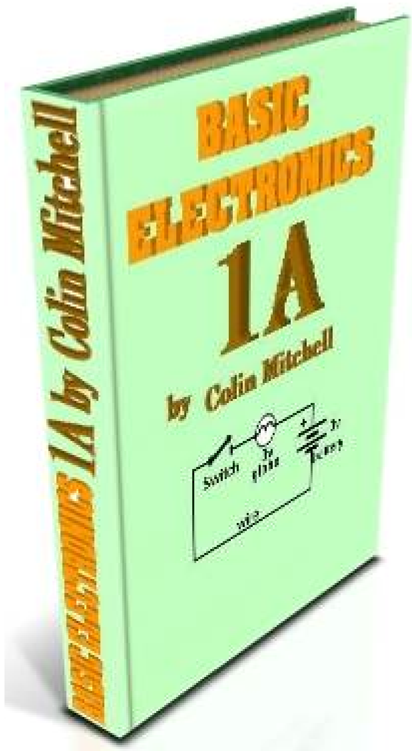
28. collector

29. (a) greencap or ceramic capacitor (b) transistor (c) resistor (d) electrolytic
    (e) battery (f) resistor

30. The current through the coil starts and stops or rises and falls at a rate equal to the frequency being reproduced.

31. Resistor and capacitor.

32. Refer to the resistor colour code calculator.



For any enquiries email Colin Mitchell

The 555 IC

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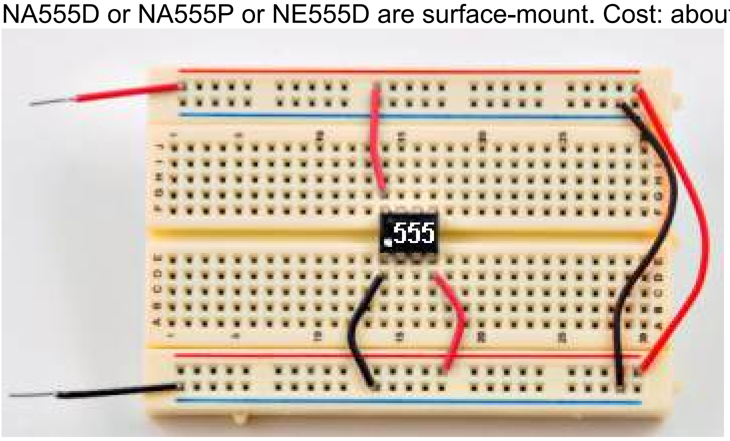
The **555 IC** is very popular, with over 150 different circuits designed around this 8-pin chip - so we are giving it a whole chapter.
The 555 is an **OSCILLATOR CHIP** without the **TIMING COMPONENTS**.
When you add a resistor and capacitor, you create a **TIME DELAY** circuit because the capacitor takes a period of time to charge via the resistor.
The **555** is connected to the join of these two components and it monitors the voltage.
When the voltage is 2/3 of the supply voltage the chip **TURNS OFF** and the output goes **LOW**.
The chip then removes the CHARGING VOLTAGE and connects the resistor to 0v rail. The capacitor begins to discharge and when the voltage is 1/3 of supply voltage, the chip **TURNS**

ON. The output goes **HIGH** and the charging resistor is connected to rail voltage to start the cycle again.
If the value of the capacitor and resistor are small (low values) the rate at which the 555 turns **ON** and **OFF** will be fast and the circuit is called an **OSCILLATOR**.
If the value of the resistor is high and the capacitor is above say 1u, the rate at which the 555 turns **ON** and **OFF** will be low and the circuit is called a **TIMER**.
The 555 can operate as a timer up to about 10 minutes and as an oscillator up to about 300kHz.
This gives an enormous range of capabilities and that's why over 150 different projects have been designed around it.
There are a number of different 555 chips, but the cheapest is called a TTL device due to the components inside it and it takes about 10mA when in a circuit. There are low-current versions called CMOS (but the output current is very small) and a 14 pin TTL version containing two 555 devices.
We will be covering the cheapest and simplest version called: NE555, or HA555 or, SE555, or CA555 (P package or DIP package). Look for the price: about 25cents to 35 cents each.
eBay: 10 items for $1.20 with free postage!
NA555D or NA555P or NE555D are surface-mount. Cost: about 45 cents.



The 555 IC fitted to bread-board with **pin 1** clearly marked with a dot.
Breadboard from eBay: $2.40 (free postage). You **must** get the breadboard with the positive and negative rails marked with red and blue lines.

Jumpers:

You can also get a pack of jumpers to connect the components. eBay: $1.70.

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You have to understand how pins 2, 3, 6 and 7 work, especially pins 2 and 6. That's why you need all the following animations.
Pin 3 is an output and will supply 200mA when it is HIGH and sink 200mA when it is LOW. Pin 7 is high and low at the same time as pin 3 but when it is HIGH, it is open-circuit and effectively "does not exist." When it is LOW, it will sink about 150mA. It is called an "open-collector" pin - meaning something has to be connected to the pin and positive-rail.
Need to watch these animations to understand how the 555 woks:

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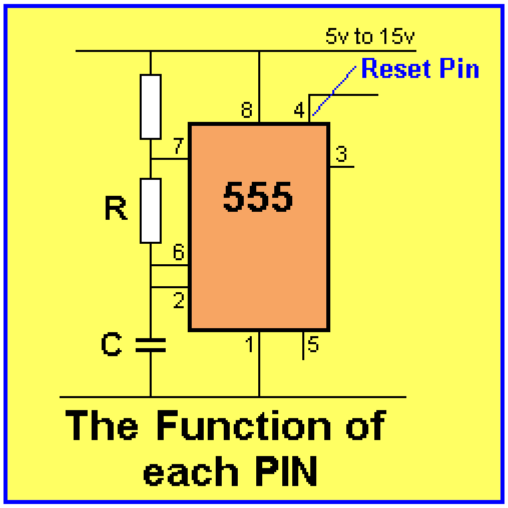
Watch this animation:	The first thing you have to understand is the function of each pin. The 555 must be drawn as shown in the diagram so all the pins are in the correct



position and they can be recognised as being a power pin, a low-voltage detector, a high-voltage detector etc and the value of the components connected to the pins will tell you the approximate frequency of the circuit.
Here is the name of each pin and its function.
This is an **ANIMATION**.
Watch it a few times to understand the function of each pin.

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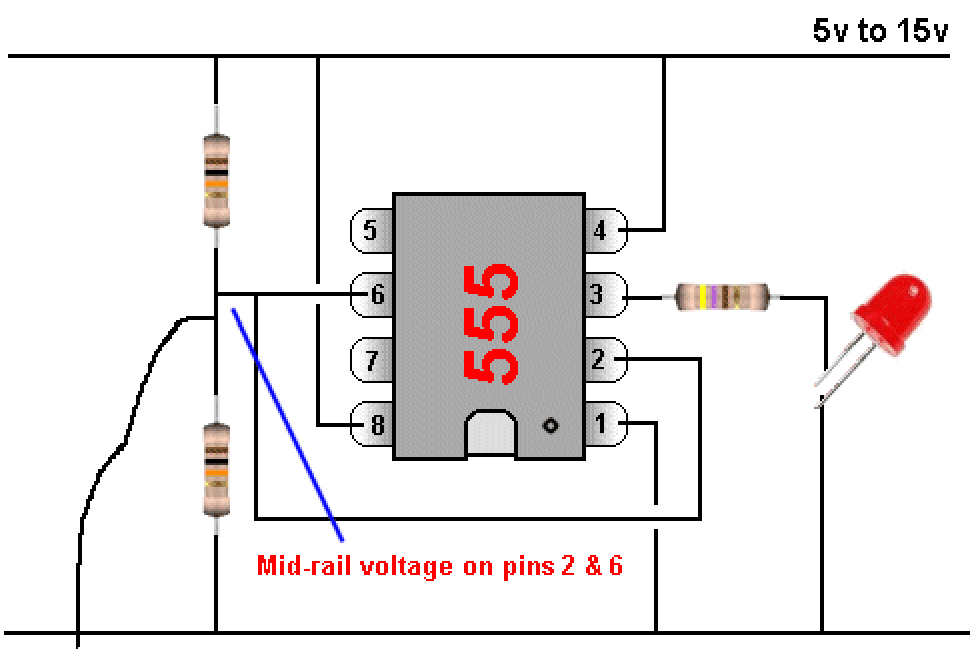
There is one more feature that needs to be discussed:
The 555 contains a FLIP-FLOP and the output can be either HIGH or LOW if the voltage on pins 2 and 6 are not at the correct levels.
If pin 6 is HIGH and pin 2 is LOW - the output will be HIGH - pin 2 is sending a "set" message
If pin 6 is HIGH and pin 2 is HIGH - the output will be LOW - pin 6 is sending a "reset" message
If pin 6 is LOW and pin 2 is LOW - the output will be HIGH - pin 2 is sending a "set" message
If pin 6 is LOW and pin 2 is HIGH - the output will be HIGH **or** LOW - this is because no pin is sending a "set" or "reset" message. The chip sometimes comes on in SET mode and sometimes in RESET mode.
Pin 2 OVER-RIDES pin 6.
When pin 2 is LOW the output of the chip is HIGH. The state of pin 6 does not matter.

The animation below shows Pins 2 and 6 connected to mid-rail voltage. This means they produce no "message" to the 555 and it will come on HIGH or LOW.
But when pin 2 see a LOW, the output goes HIGH (it does not matter if pin 6 is HIGH or LOW - pin 2 controls the 555).
The 555 is now "active" with output HIGH. When pin 6 sees a HIGH, the output goes LOW because pin 2 is not LOW and it does not control the 555.



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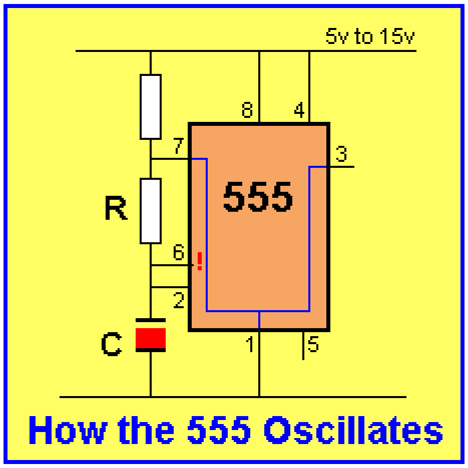
An animation of the 555:

The capacitor charges via the two resistors.
Pins 2 and 6 are high impedance pins and do not put any load on the capacitor or affect the charging or discharging.



The voltage on the capacitor is LOW and pin 2 detects this to make the output pin 3 HIGH.
When the voltage on the capacitor is 2/3 of rail voltage, pin 6 detects this value and makes the output LOW. Pins 3 and 7 work in the same sequence and pin 7 discharges the capacitor until 1/3 of rail voltage is detected by pin 2 to make the output of the 555 HIGH for the next cycle.
This is another **ANIMATION**.
Watch it a few times to understand how pin 7 discharges the capacitor.

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Pin 4 must be connected to "power rail" for the chip to "work." If it is connected to 0v, the chip does not work but still takes 10mA.
Pin 5 can be connected to a 10n capacitor if you want the output waveform to be absolutely free from "noise," but generally it is **not** connected. Too many circuits show a 10n connected to this pin when it is **NOT** necessary.

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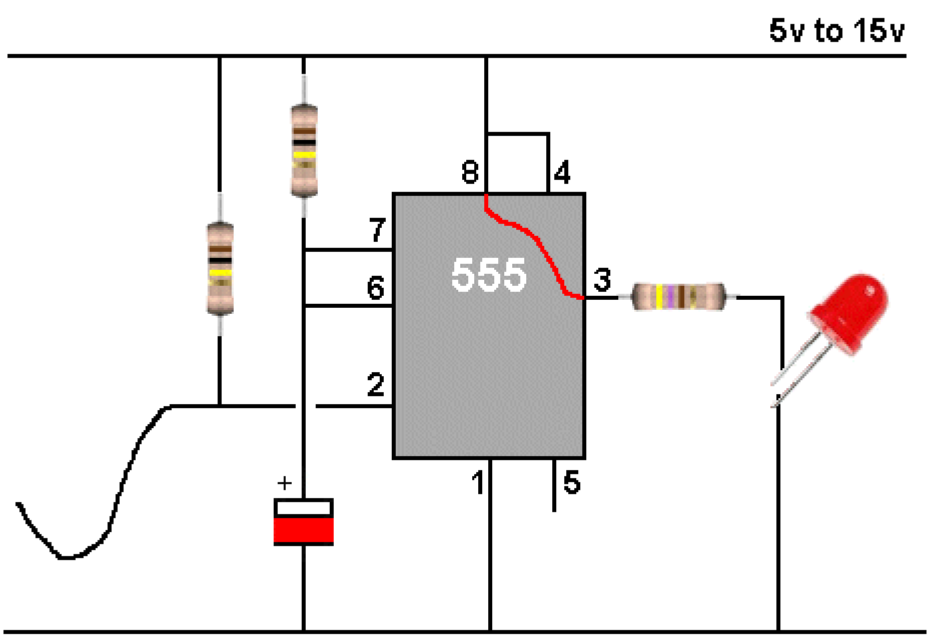
This animation shows a "one shot."
Also called: "switch debounce" or "monostable" or "pulse extender."
A "one shot" is a circuit that produces a HIGH for a short period of time after a switch is pressed. The switch must be pressed for a very short period of time (less than the length of the HIGH output). If the switch is pressed too long, the output will stay HIGH until the switch is released. The purpose of the circuit is to detect a very brief pulse and produce a clean output.
A switch is very noisy and when it is pressed, it sends lots of spikes and pulses during the time when the contacts are making connection and when they are separating. If a debounce circuit is not added, the result will be many pulses and a computer, for instance, will read this as a lot of pulses instead of a single pulse.



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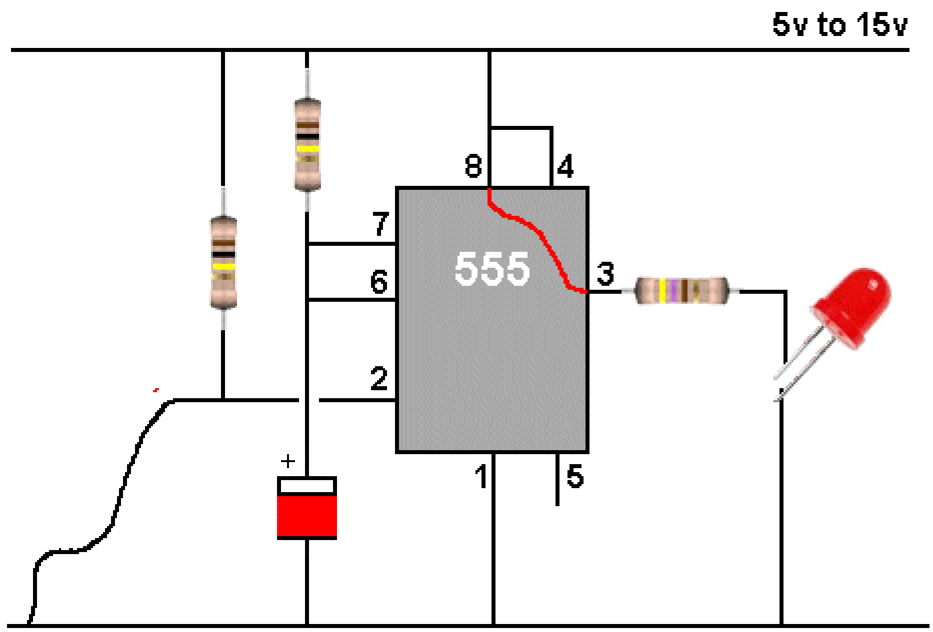
In this animation Pin 2 is LOW for too-long. See what happens to the output:



The output of the 555 does not go LOW until Pin 2 is removed from the 0v rail.

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SPOT THE MISTAKES!

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This group of circuits comes from various books and magazines that caught the author's eye due to one or more mistakes in a circuit diagram.
The best way to learn electronics is through mistakes - either yours or others.
No-one is perfect and we all make mistakes, so it's handy to see how mistakes are made and how they get through the proof-reading of a publication.
Some mistakes I have selected are a matter of opinion while others are definitely technical. Maybe I'm too critical, but that's the nature of electronics.
One of the circuits discussed in this article represents a project designed by a "fairly-competent" technical person. It is a key-hole light. He spent months on the design and travelled overseas to complete the project and organise manufacture of both the electronics and hardware. He then had 100,000 units manufactured and shipped to distributors. The unit had the batteries installed because he thought the circuit shut down to zero current. The idea was it could be operated on a display-stand so the customer could see how it worked. Unfortunately the circuit shut down to about 60uA! By the time the units hit the shops, all the batteries were dead! He had a total recall problem. He lost a fortune! All for the sake of 59uA! Who said you couldn't loose a fortune over 1mA?
This is just one instance for the need for perfection - and thorough testing.
Some of the other faults that lead to the demise of "inventors" and "suppliers" include poor quality-control where a component was missing or a wire left unsoldered. A design has to be 100% correct for it to function. So why can't we strive for a perfect layout and presentation of a circuit diagram?
Electronics is a universal language and even a circuit in overseas magazine can be viewed and interpreted correctly, even though the text may be completely indecipherable. Fortunately numerals and symbols are universal and this is just about all you need to work out how a circuit functions.
The purpose of a circuit diagram is to make it easy to understood what the circuit is doing. This means it must be CLEAR and include as much information as possible. All the component values should be included as well as chip numbers and coil winding details.
If it is user-friendly it shows it was produced by a competent technical person.
A circuit diagram is intended for you to be able to either build the device or fault-find an existing problem.
Looking up a parts list to determine the value of a component is both time-consuming and very frustrating. A diagram without any values does not give you any idea of how it works. A circuit of this nature obviously has not been produced by a competent technical person. It is essential to know the value of each component so you can mentally work out what it is doing and how it affects the other parts. How much more convenient to have the values included on a diagram.
That's what POPTRONICS **Interactive Edition** is all about - showing how to draw circuit diagrams correctly and how to "see how they work."
The secret to understanding a complex circuit is to break it into simple sections called **building blocks**. Many of them have (and will be) described in various articles in this e-magazine and this way you will be able to work out how the circuit operates.

We have picked out a set of about 10 examples, here's the first:

THE OSCILLATOR CIRCUIT

The circuit to be discussed is shown in Fig: 1.

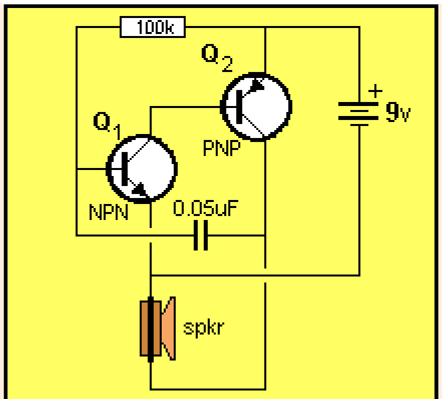


Fig: 1. An **OSCILLATOR CIRCUIT** with mistakes. See text

It is a positive-feedback amplifier but you cannot instantly see this by the way it was presented in a hobby magazine.
The layout doesn't follow any convention and you have to study it carefully to realise the speaker is connected to the output transistor.
The circuit should be much clearer. It should give an instant mental picture of the operation and you should be able to reproduce it by memory, without having to think too hard.
The second mistake is specifying non-standard values. The 0.05uF capacitor should be marked 0.047uf or more appropriately 47n. This value comes under the group called preferred values and our discussion on Page 18 of the **Basic Electronics Course** explains the range of preferred values for capacitors and also lists design values, such as 10n, 22n, 47n, and 100n. These are used in designs if the value is not important. They convey to the reader that the value is a non-critical.
The third mistake is the battery symbol. It shows two cells in series, or 3v. A 9v battery is multi-cell and the correct symbol is shown in fig: 2.
But the most dangerous fault is the connection of the two transistors directly across the supply. If you follow the circuit you will find a current path through two junctions with no current-limiting resistor.
From the positive rail, the current can flow through the base-emitter of the PNP transistor and the collector-emitter of the NPN transistor without limit.
When the circuit is first turned on, the 100k resistor begins to turn on the NPN transistor and this starts to turn on the PNP transistor. Current flows through the speaker. This puts a voltage-drop across it and creates a click. The right hand side of the 0.05u capacitor rises and takes the left side up too.
The capacitor is slightly charged and all this charge goes into the base of the NPN transistor. This turns it on almost fully. A large current flows through the collector-emitter junction of the NPN transistor and this current comes via the base-emitter junction of the PNP transistor. This current will be higher than the allowable amount and may damage the transistor.
The high current will also cause the supply voltage to fall and reduce the voltage to the speaker, so the speaker will not be as loud as in fig: 2. The corrected circuit is shown below. It is much easier to see exactly what is happening.

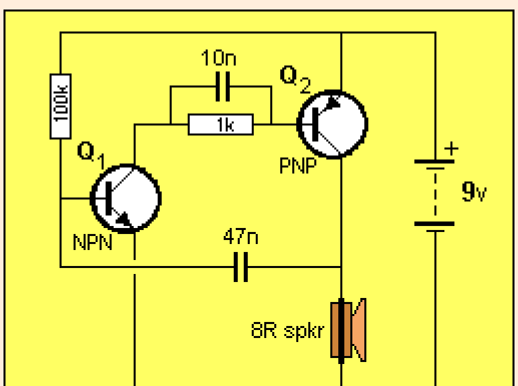


Fig: 2. The corrected **OSCILLATOR CIRCUIT**

The speaker is obviously in the collector of the output transistor and you can see how the 47n capacitor rises when the voltage across the speaker increases.

The 1k between the two transistors acts as a current limiter to prevent the two transistors being damaged.
The 10n allows a high pulse of current to flow in the base-emitter circuit of the PNP transistor, without damaging it and fully turns it on to drive the speaker.
The second circuit will take less current to achieve exactly the same result as in fig: 1, and avoid high currents flowing through the junctions of the transistors.
The second circuit clearly shows the two transistors are a directly coupled high gain amplifier with the speaker as the collector load of the output transistor.
The circuit works on regenerative action (positive feedback).
This is where one section passes a signal to another and it is amplified and returned to the first to make the signal even larger. This happens until the signal is as high as possible (generally almost as large as the supply voltage) and since it cannot get any larger, something happens to reverse the situation, so the signal gets as small as possible and the cycle repeats.
In our case the cycle starts with the 100k on the base of the first transistor charging the 47n capacitor and when the voltage is above 0.65v, the transistor begins to tun on.
This turns on the second transistor and a current flows through the collector-emitter junction and also the speaker.
When a current flows through a load such as a speaker, a voltage is developed across it and this voltage is seen by the right side of the 47n capacitor. The right side of the capacitor rises and takes the left side up with it.
The charge on the capacitor is dumped into the base of the first transistor and this makes it turn on even harder.
This action continues around the circuit until both transistors are fully turned on. This is called positive feedback.
They stay fully tuned on for a short period of time and then the capacitor runs out of charge.
This makes the NPN transistor turn off slightly. This turns off the PNP transistor and the voltage across the speaker reduces and the capacitor drops slightly. This puts less voltage on the base of the NPN transistor and it turns off. This action continues around the circuit until both transistors are fully turned off.
The 100k resistor begins to charge the 47n to start the cycle again.
This action repeats 500 to 5,000 times per second, depending on the value of the capacitor (47n) and 100k resistor. If the capacitor is reduced in value, the frequency is increased. If the resistor is increased in value, the frequency is reduced.

THE FLIP FLOP CIRCUIT

The second circuit we will discuss is shown in fig: 3. It was found in a project booklet for beginners and contains no fewer than seven mistakes. Some you will agree with while others will create a debate.

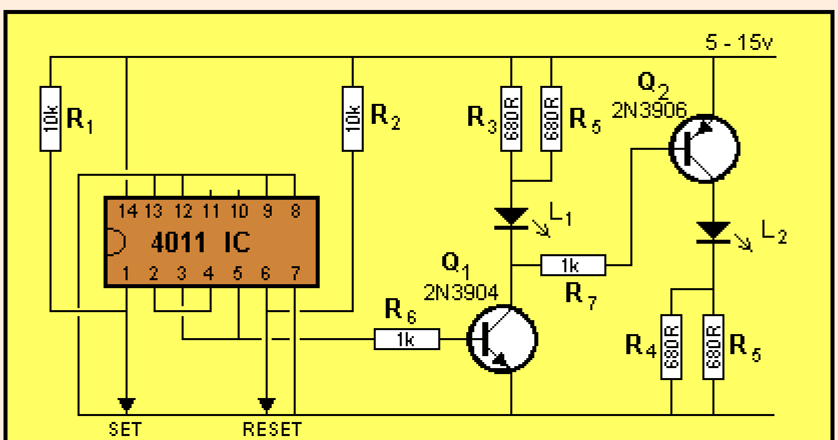


Fig: 3. The **FLIP FLOP** as presented in the project booklet

In any case, see if you can find seven things. You may not agree with everything I have found.
1. The first, and most obvious mistake is the 1k resistors on the base of the transistors. A 1k resistor is a very low value for a small-signal transistor. It will deliver about 15mA to the base and this is too high. The base should see no more than 1mA. In this case the resistor should be 10k to 47k.
2. The 4011 IC is a CMOS device and has high impedance inputs. It should have 100k to 1M for the
pull-up resistors.

3. The supply voltage of 15v is getting very close to the maximum voltage for some CMOS chips.
Some have a maximum of 15v or 18v, or 22v, depending on the manufacturer.
CMOS should be limited to 12v to be on the safe side.
4. The circuit has two 680R resistors in parallel as the load resistors for the Light Emitting Diodes. The supply voltage is in the range 5 - 15v.
With a 15v supply, the current through the LEDs will be nearly 36mA and this is higher than the allowable maximum. LEDs are rated at 20mA for normal operation. The current can be increased to 25-30mA for short periods and up to 40mA in pulse mode.
5. When designing a circuit such as this, it is normal for a switch to give a positive pulse when it is closed. This is called positive logic and is the easiest logic to understand.
The opposite logic is called negative logic in which a negative pulse (or zero pulse) is applied to an input when a switch is closed. The SET and RESET switches in fig: 3 introduce negative logic and this makes the circuit difficult to understand. (In fig: 4 we have given the switches positive logic.)
6. The LEDs are identified as L_1 and L_2. The letter 'L' is reserved for coils and inductors not LEDs. LEDs are diodes and are given the letters LED_1 , LED_2 etc.
The two additional 680R resistors have the same part number R_5. They should be R_5 and R_8. Every component must have its own separate part number. This mistake was carried through to the parts list where it specified 3 x 680R!
7. Now here is the most interesting fault.
The circuit description says both LEDs will come on when pin 3 is HIGH and go off when pin 3 is LOW. But what is the point of having the second transistor to drive the second LED? Both LEDs could be placed in series with each other and this would save 3 or 4 components.
A better arrangement is to have the circuit drive two LEDs independently as shown in fig: 4. For this, the two base resistors of the transistors go to pin 3 of the IC.
The diagram in figure 3 is not really a circuit diagram or schematic. The wiring around the chip may be suitable for the beginner so he can wire up the chip but the block diagram for the chip does not tell you anything about the type of gates inside the chip. You would have to refer to a technical manual to find out the 4011 is a quad NAND gate.
The purpose of a circuit diagram or schematic is to show all the symbols so the reader can instantly work out what is happening.
The layout in figure 3 doesn't help you understand how the circuit works and this form of presentation is to be avoided.
The preferred way of laying out the circuit is shown in fig: 4.

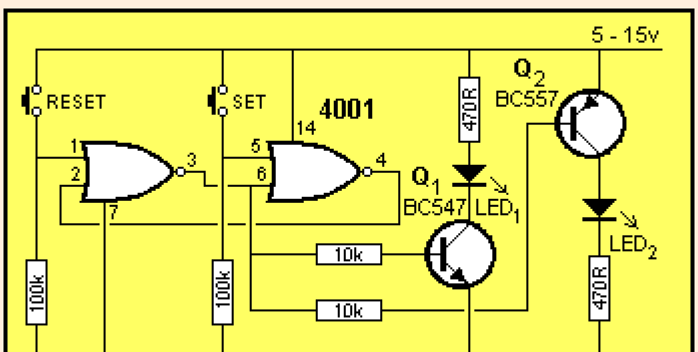


Fig: 4. The improved **FLIP FLOP** circuit

It shows the two gates used to form a **bi-stable flip flop**, while the other two gates are unused. Positive logic has been used for the two switches so that their operation is easy to understand and the resistors have been changed to the correct values. The IC has been changed to a quad NOR gate (4001) so that positive logic can be used.

AN ADJUSTABLE REGULATOR

The third faulty circuit is shown in fig: 5.

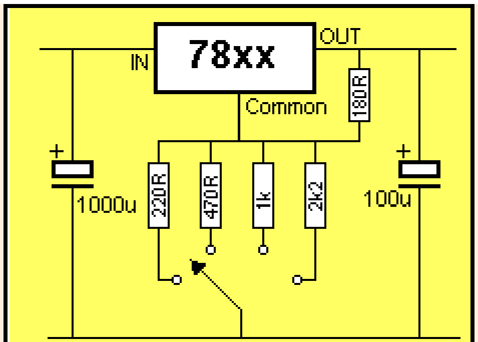


Fig: 5. A switchable **VOLTAGE REGULATOR** circuit

It centres around a Three-Terminal Regulator. These are sometimes called TTR's and all regulators are adjustable to any voltage above their minimum output voltage and up to their maximum safe working voltage, by "jacking-up" the common terminal.
For a 5v regulator the output can be between 5v and 35v. For a 12v regulator it can be 12v to 40v and for a LM 317, it can be 1.2v to 37v. There are other factors that come in to the ability of a regulator to deliver the current at a particular voltage and this is mainly the result of wattage dissipated in the package. This will be covered in other articles.
The Common terminal is sometimes called the adj (adjust) pin and any increase on this pin is passed to the output via the circuitry inside the package.
The electronics inside the package is not simply one or two transistors and a few resistors. It is a complex monitoring circuit requiring 20 or more transistors to maintain a constant output voltage over a wide range of current fluctuations. It also has thermal detection to prevent the package getting too hot and current limiting to prevent overload.
Three terminal regulators are very inexpensive for the operation they perform.
Now back to the problem. The fault with fig: 5 is mainly mechanical.
The rotary switch used to change from one voltage to another is a break-before-make type and this means there will be a very short period of time when no voltage divider resistor is connected to the ground or earth rail.
This means the 180R "pull-up" resistor will pass the full output voltage to the common pin and increase the common terminal by a value equal to the voltage of the regulator. If the regulator is a 7805, the output voltage will increase by 5v to 10v. The 10v will be passed back to the common pin and the output will rise a further 5v. The output will keep rising until it is about 4v less than the input and this could be 25v or higher!
Any voltage-sensitive equipment being supplied by the regulator will get a pulse of very high voltage during switching and may be damaged.
The correct way to add a **selector switch** to a regulator is shown in fig: 6.

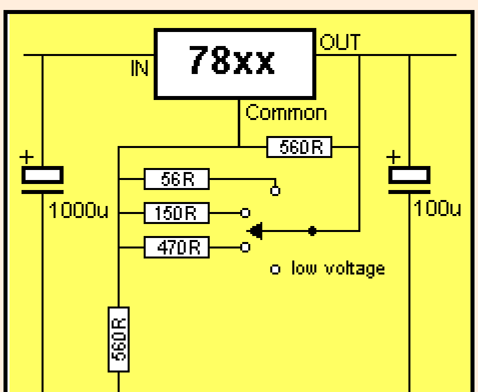


Fig: 6. The corrected circuit for the switchable **VOLTAGE REGULATOR** circuit.

When the switch is changing from one voltage to another, the output voltage DROPS momentarily to the lowest setting. IN the circuit above, the lowest setting is 50% higher than the rating of the regulator. For a 5v regulator, the lowest setting is 7v5.
The "low voltage" setting of the switch does not need any connections as it represents 7v5.
As the other positions are selected, the output voltage is jacked up and when the switch is between positions, the voltage drops to the "lowest value."
The resistance values given in the diagram are only examples and you will have to work out

values for your particular voltages.

5-LED VOLTAGE INDICATOR

The next circuit, shown in fig:7, is a very simple voltage indicator using 5 LEDs to indicate voltages from about 5.5v to 8.5v.

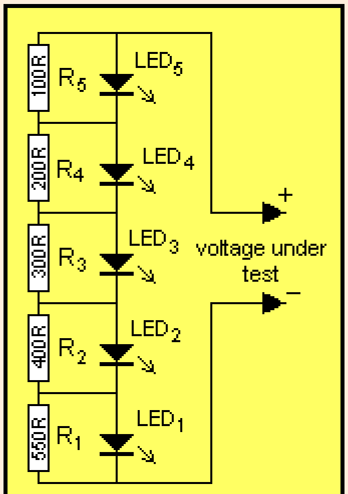


Fig: 7. A 5-LED Voltage Indicator

It's another example of putting a circuit together without actually testing it.
This is one of the things we don't do. We never present a circuit without actually trying it first because things always creep in where you least expect them. This circuit is a typical example.
The author obviously didn't try the circuit because if he had, it would have blown up!
The text says "The two test points are applied to the unknown voltage with the polarity shown."
Can you see what would happen to the circuit if the unknown voltage is 12v?
If not, we will go into a little theory about LEDs, but first let's look at the voltage at which each LED will start to illuminate.
The circuit is perfect in theory - just one resistor has been left off. The parts list did not specify the colour of the LEDs and this is important as each colour has a different characteristic voltage that develops across it and once this voltage is reached, it does not increase.
The other fault is the specification of "oddball" resistors. It doesn't really matter what voltage each LED turns on at, provided the resistors are easy to obtain.
The corrected diagram is shown below but don't refer to it until you have tried to work out what is wrong with the original circuit.
Here's how to work out the turn-on voltage for each LED.
Firstly we will specify red LEDs for the ladder and a red LED turns on when the voltage across it is 1.7v. Some red LEDs need 1.8v - 1.9v so your ladder will need to be calibrated before use.
Let us use 1.7v red LEDs. Suppose we start with a voltage that increases from zero. When the voltage is low, the LEDs exhibit infinite resistance and do not put any load on the circuit.
The only components in the circuit are the chain of resistors.
A voltage will develop across each resistor according to its value and as the voltage rises, the 550 ohm resistor will create the highest voltage across it. This means the 550 ohm resistor is the first resistor we look at.
When the voltage across it is 1.7v, each of the other resistors will have a voltage across them according to its resistance. Resistor R_2 will have 1.23v, R_3 will have 0.93v, R_4 will have 0.62v, R_5 will have 0.3v, making a total of 4.8v.
You can see the only resistor with enough voltage across it to turn on a LED is R_1 and this occurs when the test voltage is 4.8v.
Here comes the next surprise. The voltage across LED_1 does not rise any higher than 1.7v. As more current flows though the circuit, the LED gets brighter but the voltage across it does not increase.
This feature has to be taken into account when working out the rest of the calculations.
As the voltage increases, the voltage across R_2 becomes 1.7v, and LED_2 begins to turn on.
When the voltage across R_2 is 1.7v, the voltage across the total of R_3, R_4 and R_5 is 1.27 + 0.85 + 0.42 = 2.54v
This makes the test voltage = 1.7v + 1.7v + 2.54v = 5.94v.
We really don't have to get into accuracy like this but it has been presented to show you how to

work out the various values.
LED_3 turns on at 6.79v. LED_3 turns on at 7.65v and LED_5 turns on at 8.5v.
Remember what we said about the characteristic voltage of LED. The voltage does not rise above 1.7v.
If you supply the circuit with a voltage above 8.5v, the LEDs are not going to allow the voltage to rise above 8.5v and any voltage above this is simply going to drive more current through them. When the current rises above 40mA, one or more will be permanently damaged.
This has not been taken into account when the circuit was designed and is a bad omission.
The answer is the circuit shown in fig: 8:

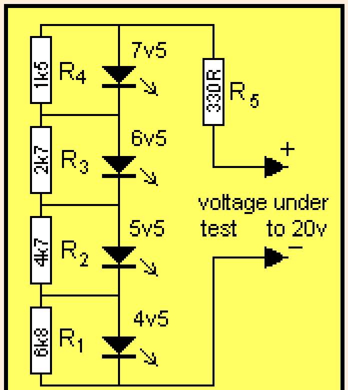


Fig: 8. A 4-LED Voltage Indicator

The solution is to include an extra resistor called the load resistor or current limit resistor and the value will be worked out by limiting the current to 40mA for the stair-case of LEDs and a maximum voltage of 20v.
By Ohms law:

$$I = \frac{E}{R}$$

$$R = \frac{20 - 6.8}{0.04}$$

$$= 330$$

use 330 ohms

Now we have to work out a set of resistances for the ladder so the LEDs come on at about the same voltages as before.
The 330R current limiting resistor sets the parameters for this circuit and has turned it into a very complex design problem.
The whole circuit will have to be designed around very low current because the 330R resistor has set the minimum current.
It works like this:
Firstly we will not be able to have 5 LEDs. Only 4 will operate with the new design.
Secondly we have to assume a LED starts to illuminate when 0.5mA is flowing through it. If you test a LED you will be able to see a faint glow when this current is flowing.
If the LEDs are exactly 1.7v devices, the top LED will turn on at 7v5 and at 9v, it will have about 6mA flowing through it.
For LED_3 to turn on at 6.5v, resistor R4 must be 1k5.
Working out the values for the staircase of resistors is a lot of work and beyond the scope of this article.
A LED is very similar to a zener diode. In fact it is exactly like a zener diode with a window so you can see the current flowing.
A red LED is a 1.7v zener diode. A green LED is about 2.1v zener and orange is about 2.3v.
As soon as the voltage reaches 1.7v or 2.1v or 2.3v, the voltage across the device does not increase. All that happens is the current through the LED increases when you try to put a higher voltage across it.
The increased current flow can be seen by the increase in the brightness of the LED.
In fact you can use a LED as a zener diode and see how a normal zener operates.
You can create any zener voltage by putting LEDs in series as shown in fig: 9.

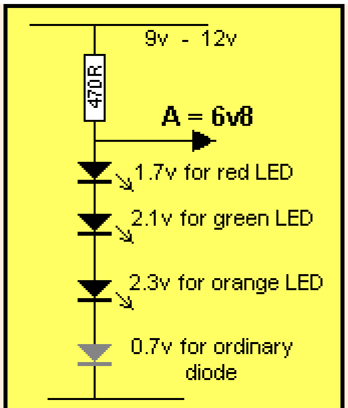
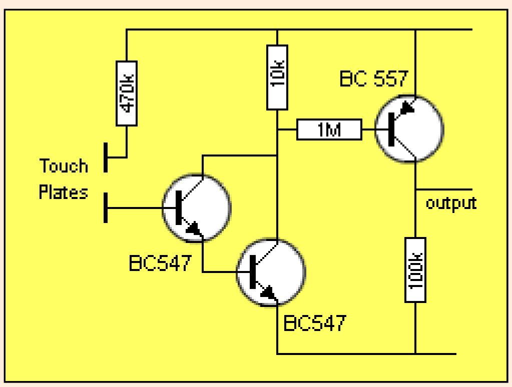


Fig: 9. Creating a ZENER diode with LEDs and an ordinary diode
corrected 10-9-05

Don't forget the current limit resistor or you will damage the LEDs, as discussed in fig: 7.
The zener voltage appears between point "A" and the 0v rail. In the example of fig: 9, the voltage will be 1.7 + 2.1 + 2.3 + 0.7 = 6.8v.
Almost any voltage from 0.7v can be created, depending on the combination of LEDs and ordinary signal diodes.

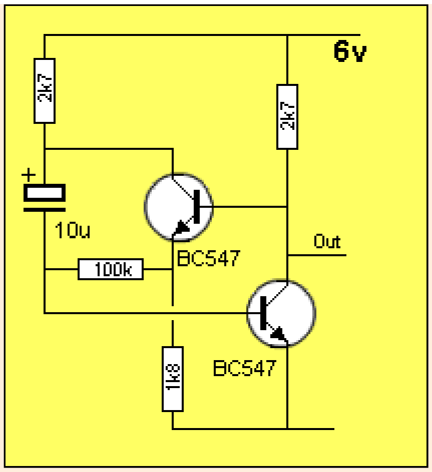
THE TOUCH SWITCH

The following **Touch Switch** circuit misses the point of the high impedance front-end. The 1M on the base of the BC557 is a very high value and will give the transistor very little current capability to make the output of the circuit HIGH.
The super-alpha pair on the front end (made up of the two BC547 transistors) has already created a low impedance output (as shown by the 10k on the output), so the line can be driven low when a finger is placed on the Touch Plates. The 1M could be lowered to 47k to give the output more "driving power" and show that the front-end has produced a low impedance arrangement.



THE OSCILLATOR

Here's an oscillator circuit that doesn't work:



It does not provide a HIGH above 50% of rail voltage and this is insufficient to guarantee clocking of a digital IC. A signal above 70% of rail voltage is needed. In 20 years, the magazine using the circuit in one of its projects did not point out the dangers. It would be a simple matter of viewing the circuit on a CRO to realise the output goes +50% and –20%.
Maybe that's why this circuit has never been repeated in any other magazine.

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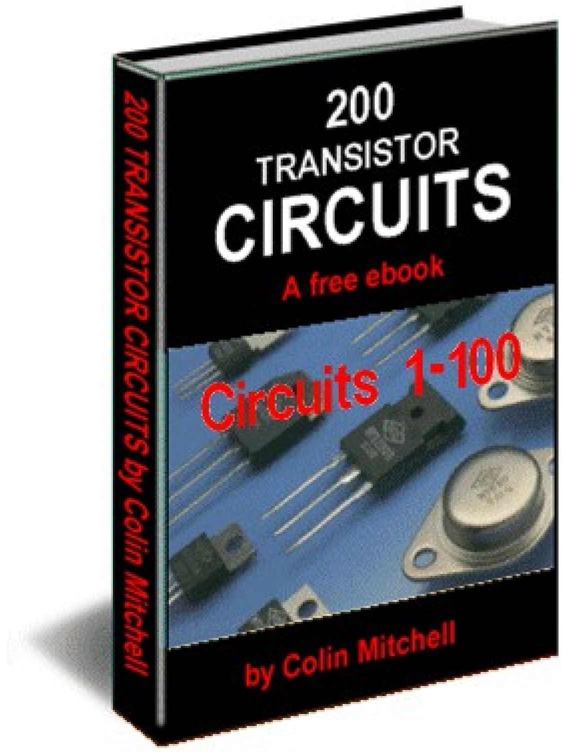

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Talking Electronics

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email Colin Mitchell: talking@tpg.com.au

INTRODUCTION

This e-book contains 100 transistor circuits. The second part of this e-book will contain a further 100 circuits.
Most of them can be made with components from your "junk box" and hopefully you can put them together in less than an hour.
The idea of this book is to get you into the fun of putting things together and there's nothing more rewarding than seeing something work.
It's amazing what you can do with a few transistors and some additional components. And this is the place to start.
Most of the circuits are "stand-alone" and produce a result with as little as 5 parts.
We have even provided a simple way to produce your own speaker transformer by winding turns on a piece of ferrite rod. Many components can be obtained from transistor radios, toys and other pieces of discarded equipment you will find all over the place.
To save space we have not provided lengthy explanations of how the circuits work. This has already been covered in TALKING ELECTRONICS Basic Electronics Course, and can be obtained on a CD for $10.00 (posted to anywhere in the world) See Talking Electronics website for more details: http://www.talkingelectronics.com
Transistor data is at the bottom of this page and a transistor tester circuit is also provided.
There are lots of categories and I am sure many of the circuits will be new to you, because some of them have been designed recently by me.
Basically there are two types of transistor: PNP and NPN.
We have labelled the NPN transistor as BC547. This means you can use ANY NPN transistor, such as 2N2222, BC108, 2N3704, BC337 and hundreds of others. Some circuits use TUN for Transistor Universal NPN and this is the same as our reasoning - the transistor-type is just to let you know it is not critical.
BC557 can be replaced by: 2N3906, BC327 and many others.
Don't worry too much about the transistor-type. Just make sure it is NPN, it this is the type needed.
If it is an unknown transistor-type, you need to identify the leads then put it in the circuit.
You have a choice of building a circuit "in the air," or using an experimenter board (solderless breadboard) or a matrix board or even a homemade printed circuit board. The choice is up to you but the idea is to keep the cost to a minimum - so don't buy anything expensive.
If you take parts from old equipment it will be best to solder them together "in the air" (as they will not be suitable for placing on a solderless breadboard as the leads will be bent and very short).
This way they can be re-used again and again.
No matter what you do, I know you will be keen to hear some of the "noisy" circuits in operation.
Before you start, the home-made **Speaker Transformer** project and Transistor Tester are the first things you should look at.
If you are starting in electronics, see the **World's Simplest Circuit.** It shows how a transistor works and three transistors in the **8 Million Gain** project will detect microscopic levels of static electricity! You can look through the Index but the names of the projects don't give you a full description of what they do. You need to look at the circuits. And I am sure you will.

KIT OF PARTS

Talking Electronics supplies a kit of parts that can be used to build the majority of the circuits in

this book.
The kit costs $15.00 plus postage.

BUY NOW

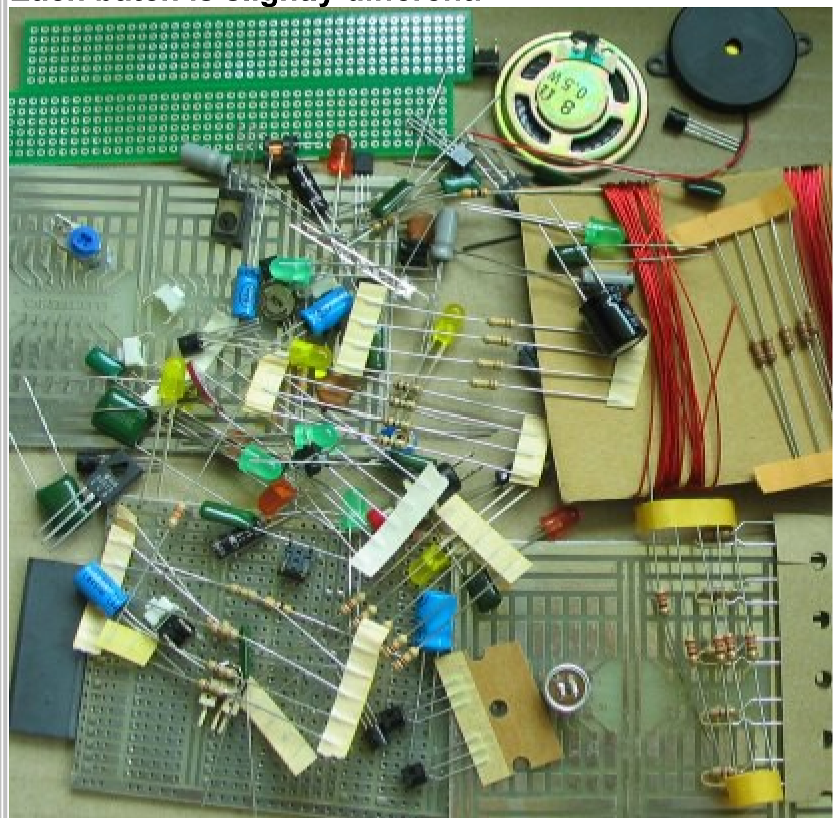
Kit for Transistor Circuits - $15.00

A kit of components to make many of the circuits presented in this eBook is available for $15.00 plus $7.00 post.
Or email Colin Mitchell: talking@tpg.com.au

The kit contains the following components:
(plus **extra** 30 resistors and 10 capacitors for experimenting), plus:

3 - 47R
5 - 220R
5 - 470R
5 - 1k
5 - 4k7
5 - 10k
2 - 33k
4- 100k
4 - 1M
1 - 10k mini pot
1 - 100k mini pot
2 - 10n
2 - 100n
5 - 10u electrolytics
5- 100u electrolytics
5 - 1N4148 signal diodes
6 - BC547 transistors - NPN - 100mA
2 - BC557 transistors - PNP - 100mA
1 - BC338 transistor - NPN - 800mA
3 - BD679 Darlington transistors - NPN - 4amp
5 - red LEDs
5 - green LEDs
5 - orange LEDs
2 - super-bright WHITE LEDs - 20,000mcd
1 - 3mm or 5mm flashing LED
1 - mini 8R speaker
1 - mini piezo
1 - LDR (Light Dependent Resistor)
1 - electret microphone
1m - 0.25mm wire
1m - 0.5mm wire
1 - 10mH inductor
1 - push button
5 - tactile push buttons
1 - **Experimenter Board** (will take 8, 14 and 16 pin chips)
5 - mini Matrix Boards: 7 x 11 hole,
11 x 15 hole, 6 x 40 hole, surface-mount 6 x 40 hole board or others.

Photo of kit of components.
Each batch is slightly different:



There are more components than you think. . . plus an extra bag of approx 30 components. The 8 little components are switches and the LDR and flashing LED is hiding.
In many cases, a resistor or capacitor not in the kit, can be created by putting two resistors or capacitors in series or parallel or the next higher or lower value can be used.

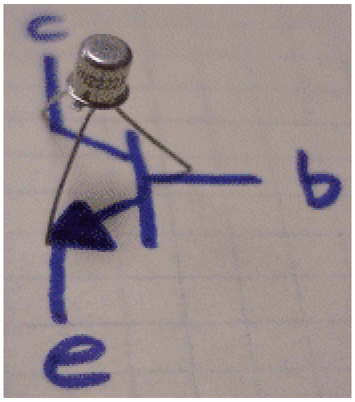
Don't think transistor technology is obsolete. Many complex circuits have one or more transistors to act as buffers, amplifiers or to connect one block to another. It is absolutely essential to understand this area of electronics if you want to carry out design-work or build a simple circuit to carry out a task.

We also have an eBook: **THE TRANSISTOR AMPLIFIER** with over 100 different transistor circuits . . . proving the transistor can be connected in so many ways.

THEORY

Read the full article HERE (the Transistor Amplifier eBook)

The first thing you will want to know is: **HOW DOES A TRANSISTOR WORK**?



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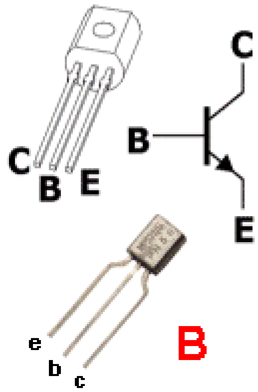

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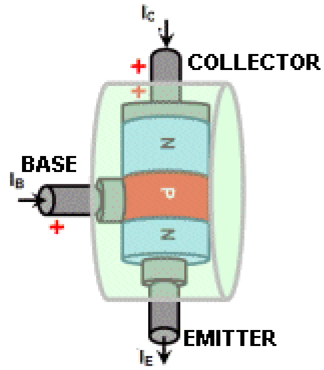

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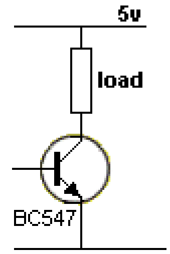

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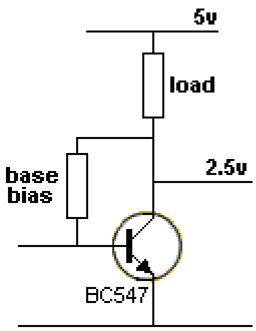

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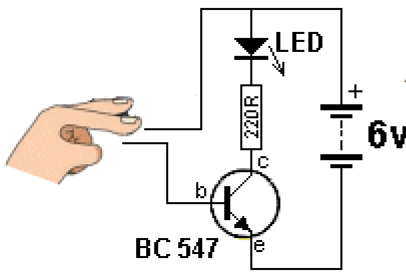

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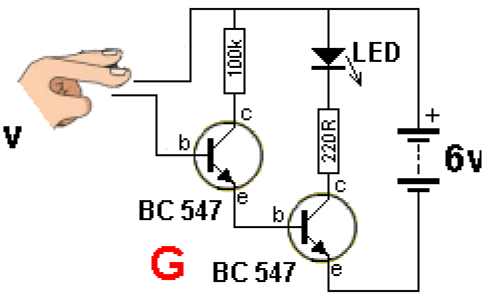

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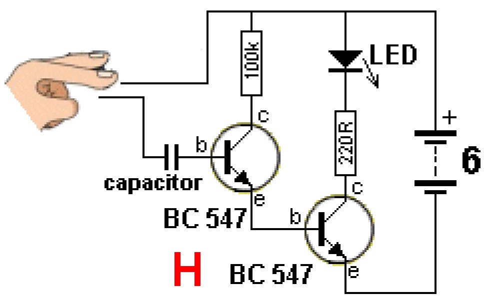

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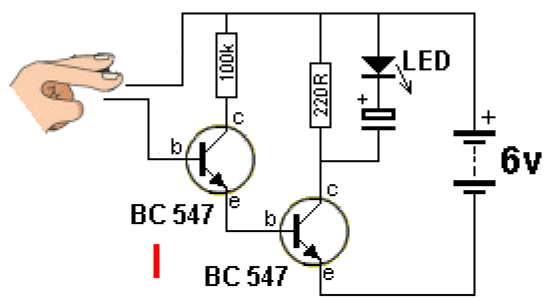


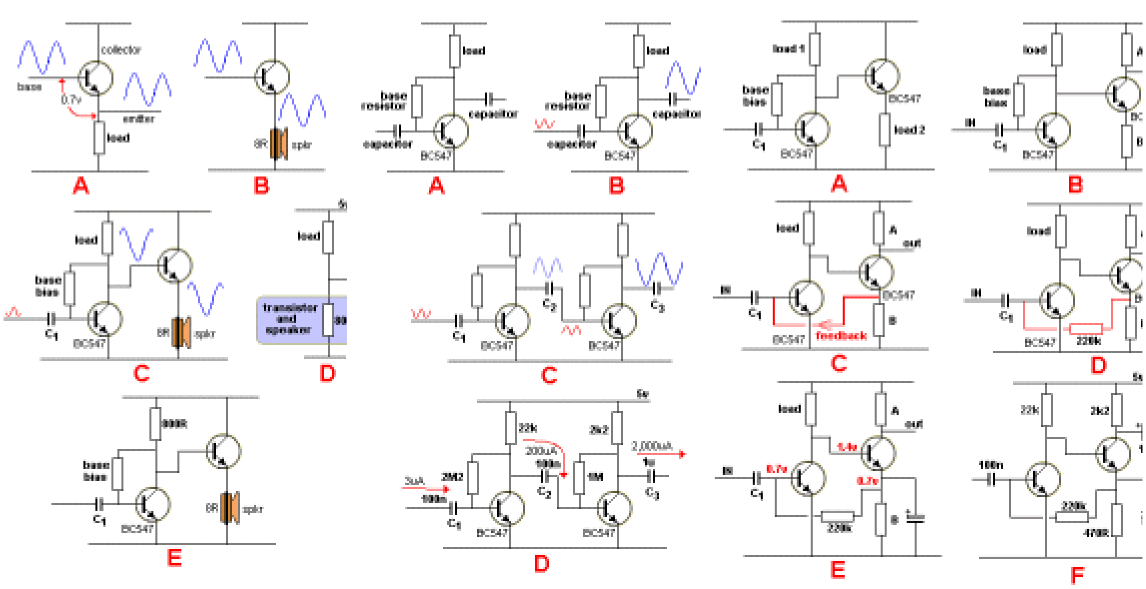
I

Diagram "A" shows an NPN transistor with the legs covering the symbol showing the name for each lead.
The transistor is a "general purpose" type and and is the smallest and cheapest type you can get. The number on the transistor will change according to the country where the circuit was designed but the types we refer to are all the SAME.
Diagram "B" shows two different "general purpose" transistors and the different pinouts. You need to refer to data sheets or test the transistor to find the correct pinout.
Diagram "C" shows the equivalent of a transistor as a water valve. As more current (water) enters the base, more water flows from the collector to the emitter.
Diagram "D" shows the transistor connected to the power rails. The collector connects to a resistor called a LOAD and the emitter connects to the 0v rail or earth or "ground."
Diagram "E" shows the transistor in SELF BIAS mode. This is called a COMMON EMITTER stage and the resistance of the BASE BIAS RESISTOR is selected so the voltage on the collector is half-rail voltage. In this case it is 2.5v.
To keep the theory simple, here's how you do it. Use 22k as the load resistance.
Select the base bias resistor until the measured voltage on the collector 2.5v. The base bias will

be about 2M2.
This is how the transistor reacts to the base bias resistor:
The base bias resistor feeds a small current into the base and this makes the transistor turn on and create a current-flow though the collector-emitter leads.
This causes the same current to flow through the load resistor and a voltage-drop is created across this resistor. This lowers the voltage on the collector.
The lower voltage causes a lower current to flow into the base and the transistor stops turning on a slight amount. The transistor very quickly settles down to allowing a certain current to flow through the collector-emitter and produce a voltage at the collector that is just sufficient to allow the right amount of current to enter the base.
Diagram "F" shows the transistor being turned on via a finger. Press hard on the two wires and the LED will illuminate brighter. As you press harder, the resistance of your finger decreases. This allows more current to flow into the base and the transistor turns on harder.
Diagram "G" shows a second transistor to "amplify the effect of your finger" and the LED illuminates about 100 times brighter.
Diagram "H" shows the effect of putting a capacitor on the base lead. The capacitor must be uncharged and when you apply pressure, the LED will flash brightly then go off. This is because the capacitor gets charged when you touch the wires. As soon as it is charged NO MORE CURRENT flows though it. The first transistor stops receiving current and the circuit does not keep the LED illuminated. To get the circuit to work again, the capacitor must be discharged. This is a simple concept of how a capacitor works. A large-value capacitor will keep the LED illuminated for a longer period of time.
Diagram "I" shows the effect of putting a capacitor on the output. It must be uncharged for this effect to work. We know from Diagram G that the circuit will stay on when the wires are touched but when a capacitor is placed in the output, it gets charged when the circuit turns ON and only allows the LED to flash.

1. This is a simple explanation of how a transistor works. It amplifies the current going into the base about 100 times and the higher current flowing through the collector-emitter leads will illuminate a LED.
2. A capacitor allows current to flow through it until it gets charged. It must be discharged to see the effect again.

Read the full article HERE



INCREASING THE VOLTAGE

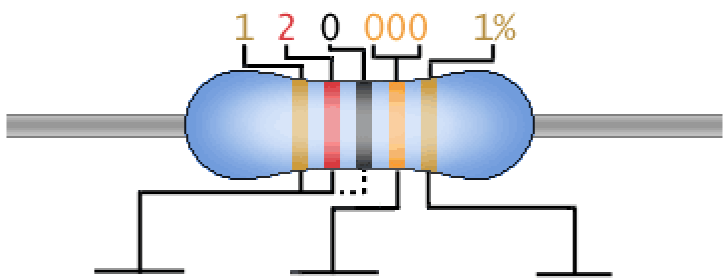
You can change the voltage of many circuits from 6v to 12v or 3v to 6v without altering any of the values. I can see instantly if this is possible due to the value of the components and here's how I do it:
Look at the value of the resistors driving the load(s).
Work out the current entering each load and see if it is less than the maximum allowable.
Then, take a current reading on the lower voltage.
Increase the voltage to the higher value and take another reading.
In most cases the current will increase to double the value (or a little higher than twice the original value).
If it is over 250% higher, you need to feel each of the components and see if any are getting excessively hot.

If any LEDs are taking excessive current, double the value of the current-limiting resistor.
If any transistor is getting hot, increase the value of the load resistor.
In most cases, when the voltage is doubled, the current will will crease to double the original. This means the circuit will consume 4 times the original energy.
This is just a broad suggestion to answer the hundreds of emails I get on this topic.

CONTENTS **circuits in red are in 101-200 Circuits**
Note: **All** circuits use 1/4 watt resistors unless specified on the diagram.

Light Alarm-1 Light Alarm-2 Light Alarm-3 Light Extender for Cars Limit Switches Listener - phone amplifier Logic Probe - Simple - Simple with PULSE Logic Probe with Pulse Low fuel Indicator Low Mains Drop-out Low Voltage cut-out Low-High Voltage Cutout Low Voltage Flasher Mains Detector Mains Hum Detector Mains Night Light Make any capacitor value Make any resistor value Make Time Fly! Make you own 1watt LED Making 0-1A Ammeter Mains Night Light Make any capacitor value Make any resistor value Metal Detector Metal Detector MkII Metal Detector - Nail Finder METAL DETECTORS - article	20 LEDs on 12v supply 24v to 12v for charging 27MHz Door Phone 27MHz Field Strength Meter 27MHz Transmitter 27MHz Transmitter - no Xtal 27MHz Transmitter-Sq Wave 27MHz Transmitter-2 Ch 27MHz Transmitter-4 Ch 27MHz Receiver 27MHz Receiver-2 240v Detector 240v - LEDs 303MHz Transmitter

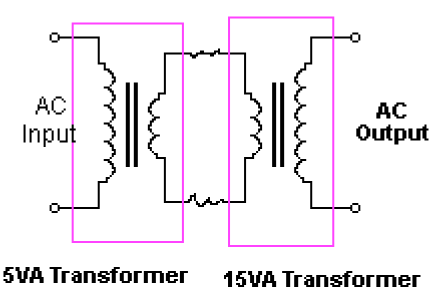
RESISTOR COLOUR CODE



0 Black	**ohms Black**	
1 Brown	10 Brown	1% Brown
2 Red	100 Red	2% Red
3 Orange	1000 Orange	
4 Yellow	10000 Yellow	
5 Green	100000 Green	
6 Blue	1000000 Blue	
7 Violet		
8 Gray	0.1 Gold	5% Gold
9 White	0.01 Silver	10% Silver

SAFE 240v SUPPLY

When working on any project that connects to the "mains," it is important to take all precautions to prevent electrocution.
This project provides 240v AC but the current it limited to 60mA if a 15 watt transformer is used. Although the output can produce a nasty shock and the voltage will kill you, the circuit provides isolation from the mains and if a short-circuit occurs, it will not blow a fuse, but the transformers will get very hot as start to buzz.
You can use any two identical transformers and the wattage of either transformer will determine the maximum output wattage.
If you don't use identical transformers, the output voltage will be higher or lower than the "mains" voltage and the wattage will be determined by the smaller transformer.

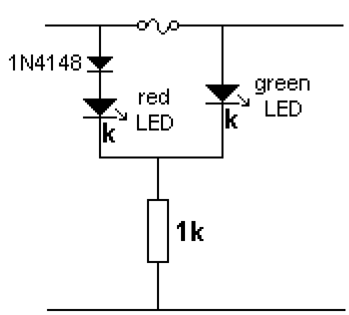


This arrangement is not perfectly safe, but is the best you can

get when working on projects such as switch-mode power supplies, capacitor-fed down-lights etc.

RECHARGEABLE BATTERY CAPACITY

This simple circuit tests the capacity of a rechargeable cell. Connect a 4R7 (yellow-purple-gold-gold) resistor across the terminals of a clock mechanism and fit a fully charged rechargeable cell. Set the hands to 12 O'Clock and the clock will let you know how long the cell lasted until the voltage reached about 0.8v.
Now fit another cell and see how long it lasts. You cannot work out the exact capacity of a cell but you can compare one cell with another. The initial current is about 250mA for a 1.2v cell.

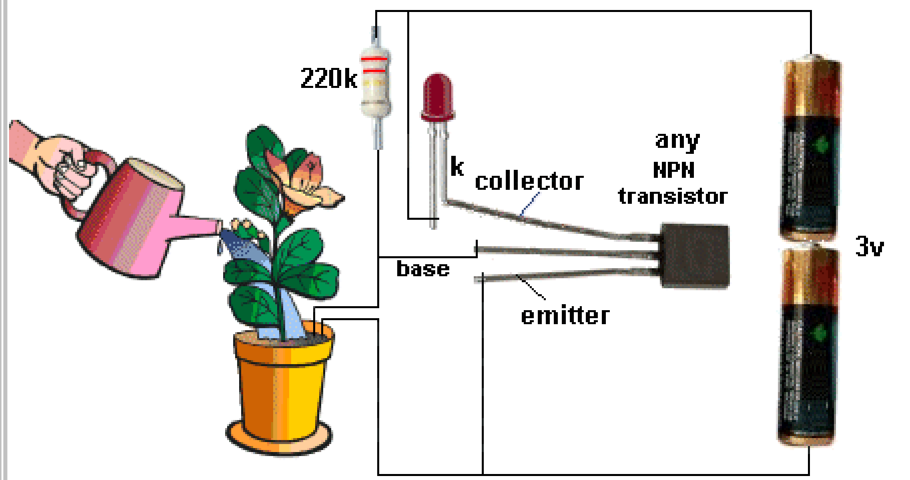


BLOWN FUSE INDICATOR

This circuit indicates when a fuse is "blown."

PLANT NEEDS WATERING

This circuit indicates when the soil is dry and the plant needs watering. The circuit does not have a current-limiting resistor because the base resistor is very high and the current through the transistor is only 2mA. Don't change the supply voltage or the 220k as these two values are correct for this circuit.



THE SOLAR PANEL
This will clear-up a lot of mysteries of the **solar panel**.
Many solar panels produce 16v - 18v when lightly loaded, while other 12v solar panels will not charge a 12v battery.
Some panels say "nominal voltage," some do not give any value other than 6v or 12v, and some specify the wrong voltage. You can't work with vague specifications. You need to know accurate details to charge a battery from a solar panel.
There are 3 things you have to know before buying a panel or connecting a panel to a battery.

1. The **UNLOADED VOLTAGE**.
2. The voltage of the panel when delivering the rated current. Called the **RATED VOLTAGE**
3. The **CURRENT**.

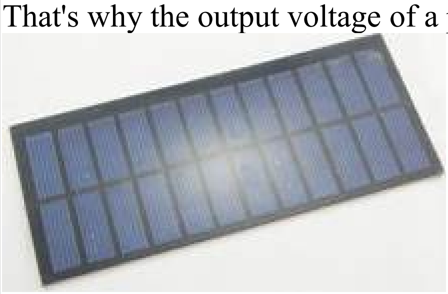
1. The **Unloaded Voltage** is the voltage produced by the panel when it is lightly loaded. This voltage is very important because a 12v battery will produce a "floating voltage" of about 15v when it is fully charged and it will gradually rise to this voltage during the charging period. This means the panel must be able to deliver more than 15v so it will charge a 12v battery.
Sometimes there is a diode and a charging circuit between the panel and battery and these devices will drop a small voltage, so the panel must produce a voltage high enough to allow for them.
The **Unloaded Voltage** can sometimes be determined by counting the

number of cells on the panel as each cell will produce 0.6v.
If you cannot see the individual cells, use a multimeter to read the voltage under good illumination and watch the voltage rise. You can place a 100 ohm resistor across the panel to take readings.

2. The **RATED VOLTAGE** is the guaranteed voltage the panel will deliver when full current is flowing.   This can also be called the Nominal Voltage, however don't take anything for certain. Take readings of your own. The Rated Voltage (and current) is produced when the panel receives bright sunlight. This may occur for only a very small portion of the day.

You can clearly see the 11 cells of this panel and it produces 6.6v when lightly loaded. It will barely produce 6v when loaded and this is **NOT ENOUGH** to charge a 6v battery.

This panel claims to be 18v, but it clearly only produces 14.4v. This is not suitable for charging a 12v battery. When you add a protection diode, the output voltage will be 13.8v. A flat battery being charged will reach 13.8v very quickly and it will not be charged any further. That's why the output voltage of a panel is so important.



This is a genuine 18v panel:

The panel needs to produce 17v to 18v so it will have a small "overhead" voltage when the battery reaches 14.4v and

it will still
be able to
supply
energy into
the battery
to
complete
the
charging
process.

3. The **Rated Current** is the maximum current the panel will produce when receiving full sunlight.
The current of a panel can be worked out by knowing the wattage and dividing by the unloaded voltage.
A 20 watt 18v panel will deliver about 1 amp.

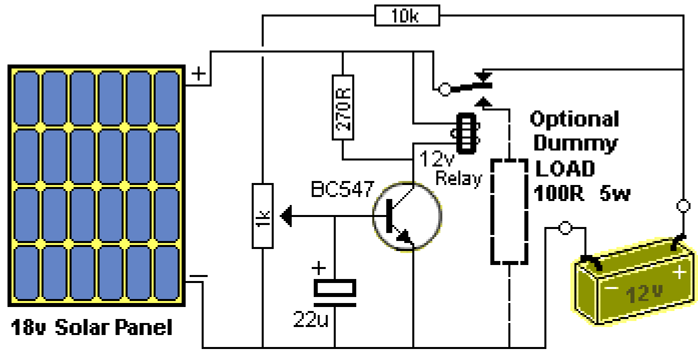
CHARGING A BATTERY
A solar panel can be used to directly charge a battery without any other components. Simply connect the panel to the battery and it will charge when the panel receives bright sunlight - providing the panel produces a voltage least 30% to 50% more than the battery you are charging.
Here's some amazing facts:
The voltage of the panel does not matter and the voltage of the battery does not matter. You can connect any panel to any battery - providing the panel produces a voltage least 30% to 50% more than the battery you are charging.
The output voltage of the panel will simply adapt to the voltage of the battery. Even though there is a voltage mismatch, there is **NO** "lost" or wasted energy. An 18v panel "drives into" a 12v battery with the maximum current it can produce when the intensity of the sun is a maximum.
To prevent too-much mismatch, it is suggested you keep the panel voltage to within 150% of the battery voltage. (6v battery - 9v max panel, 12v battery - 18v max panel, 24v battery - 36v max panel).
But here's the important point: To prevent overcharging the battery, the wattage of the panel is important.
If the wattage of an 18v panel is 6watts, the current is 6/18 = 0.33 amps = 330mA.
To prevent overcharging a battery, the charging current should not be more than one-tenth its amp-hr capacity.
For instance, a 2,000mAhr set of cells should not be charged at a rate higher than 200mA for 14 hours. This is called its 14-hour rate.
But this rating is a CONSTANT RATING and since a solar panel produces an output for about 8 hours per day, you can increase the charging current to 330mA for 8 hours. This will deliver the energy to fully charge the cells.
That's why a 6 watt panel can be directly connected to a set of (nearly fully discharged) 2,000mAhr cells.
For a 12v 1.2AHr battery, the charging current will be 100mA for 12 hours or 330mA for 4 hours and a regulator circuit will be needed to prevent overcharging.
For a 12v 4.5AHr battery, the charging current will be 375mA for 12 hours and a larger panel will be needed.

ADDING A DIODE
Some solar panels will discharge the battery (a small amount) when it is not

receiving sunlight and a diode can be added to prevent discharge. This diode drops 0.6v when the panel is operating and will reduce the maximum current (slightly) when the panel is charging the battery. If the diode is Schottky, the voltage-drop is 0.35v.
Some panels include this diode - called a BYPASS DIODE.

PREVENTING OVERCHARGING
There are two ways to prevent overcharging the battery.
1. Discharge the battery nearly fully each night and use a panel that will only deliver 120% of the amp-hour capacity of the battery the following day.
2. Add a **VOLTAGE REGULATOR**.

Here is the simplest and cheapest regulator to charge a 12v battery.
Full details of how the circuit works and setting up the circuit is HERE.
The solar panel must be able to produce at least 16v on NO LOAD. (25-28 cells). The diagram only shows a 24 cell panel - it should be 28 cells.
The only other thing you have to consider is the wattage of the panel. This will depend on how fast you want to charge the battery and/or how much energy you remove from the battery each day and/or the amp-Hr capacity of the battery.
For instance, a 12v 1.2A-Hr battery contains 14watt-hours of energy. An 6watt panel (16v to 18v) will deliver 18watt-hours (in bright sunlight) in 3 hours. The battery will be fully charged in 3 hours.

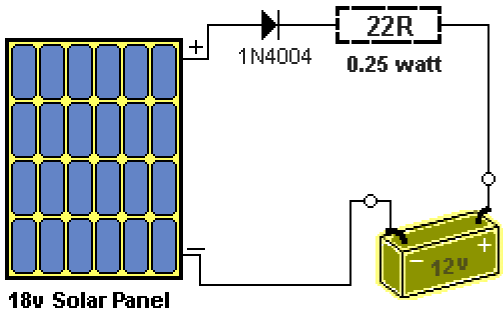


SOLAR BATTERY CHARGER / REGULATOR

The pot is adjusted so the relay drops-out at 13.7v
The charger will turn **ON** when the voltage drops to about 12.5v.
The 100R Dummy LOAD will absorb 3.25 watts and that is the maximum wattage the panel will produce with 100R load.

CHARGE CURRENT

Here is a very clever circuit to find the charging current, if you don't have a



multimeter.

Connect a 22R 0.25 watt resistor in series with the battery and hold your finger on the resistor. The resistor will get very hot if 100mA or more is flowing.
This resistor will indicate ONE WATT of energy is flowing into the battery, but we are using a 0.25 watt resistor to measure the heat as this represents "LOST ENERGY" and we want to keep the losses to a minimum.
To get some idea of 0.25watt of heat, place a 560R 0.25watt resistor across the terminals of a battery.
This is 250mW of heat and is your reference.

A 1.2A-Hr 12 volt battery has 14 watts of energy and if you are charging at ONE WATT, it will take about 16 hours to fully charge the battery.

This circuit can be used when charging a battery from your car, from a solar panel, a battery charger or a pulsed solar-charging circuit. It is also a SAFETY CIRCUIT as it will limit the current to 100mA. If the current is higher than 130mA, the resistor will hot and start to smell.

Note: when the 22R is removed, the current flowing into the battery WILL INCREASE.
The increase may be only 10% from some chargers, but can be as high as 100% OR MORE if the battery is connected to the cigarette lighter plug in your car.

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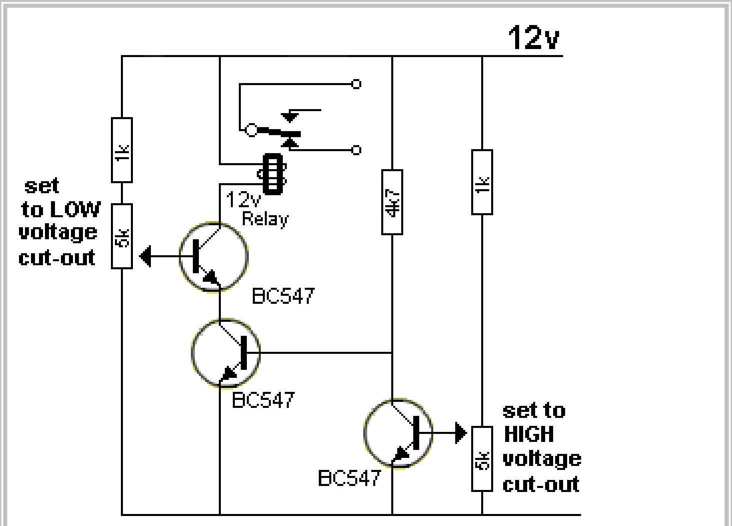
HIGH-LOW VOLTAGE CUT-OUT



This circuit will turn off the relay when the voltage is above or below the "set-points.";
You need either a variable power supply or a 12v battery and an extra 1.5v battery.
Turn the LOW voltage cutout trim pot to mid way and connect the 13.5v supply. Turn the HIGH voltage trim pot to the high end and the relay will turn off.
Now turn the 1.5v battery around the other way and adjust the LOW voltage trim pot to the 10.5v supply.

See resistors from 0.22ohm to 22M in full colour at bottom of this page and another resistor table

TESTING AN unknown TRANSISTOR

The first thing you may want to do is test an unknown transistor for COLLECTOR, BASE AND EMITTER. You also need to know if it is NPN or PNP.
You need a cheap multimeter called an ANALOGUE METER - a multimeter with a scale and pointer (needle).
It will measure resistance values (normally used to test resistors) - (you can also test other components) and Voltage and Current. We use the resistance settings.
It may have ranges such as "x10" "x100" "x1k" "x10"
Look at the resistance scale on the meter. It will be the top scale.
The scale starts at zero on the right and the high values are on the left. This is opposite to all the other scales. .
When the two probes are touched together, the needle swings FULL SCALE and reads "ZERO." Adjust the pot on the side of the meter to make the pointer read exactly zero.

How to read: "x10" "x100" "x1k" "x10"

Up-scale from the zero mark is "1"
When the needle swings to this position on the **"x10"** setting, the value is 10 ohms.
When the needle swings to "1" on the **"x100"** setting, the value is 100 ohms.

When the needle swings to "1" on the **"x1k"** setting, the value is 1,000 ohms = 1k.
When the needle swings to "1" on the **"x10k"** setting, the value is 10,000 ohms = 10k.
Use this to work out all the other values on the scale.
Resistance values get very close-together (and very inaccurate) at the high end of the scale. [This is just a point to note and does not affect testing a transistor.]

Step 1 - FINDING THE BASE and determining NPN or PNP

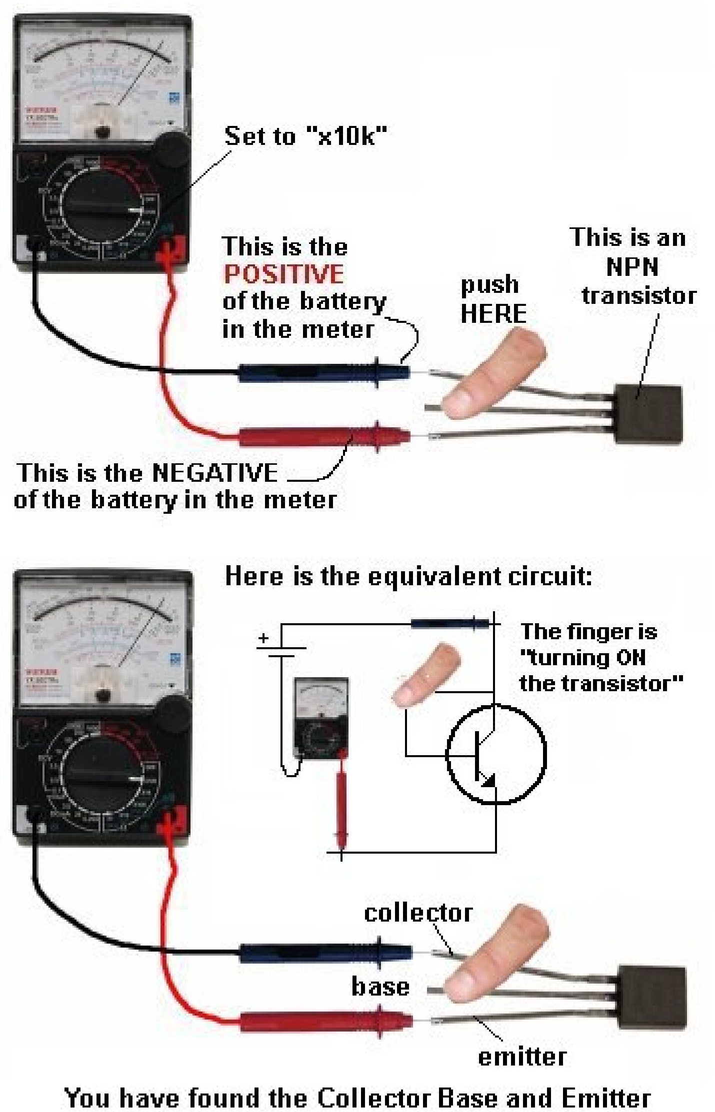
Get an **unknown transistor** and test it with a multimeter set to **"x10"**
Try the 6 combinations and when you have the black probe on a pin and the red probe touches the other pins and the meter swings nearly full scale, you have an **NPN transistor**. The black probe is **BASE**
If the red probe touches a pin and the black probe produces a swing on the other two pins, you have a **PNP transistor**. The red probe is **BASE**
If the needle swings FULL SCALE or if it swings for more than 2 readings, the transistor is FAULTY.

This is an NPN transistor
The black probe is the BASE

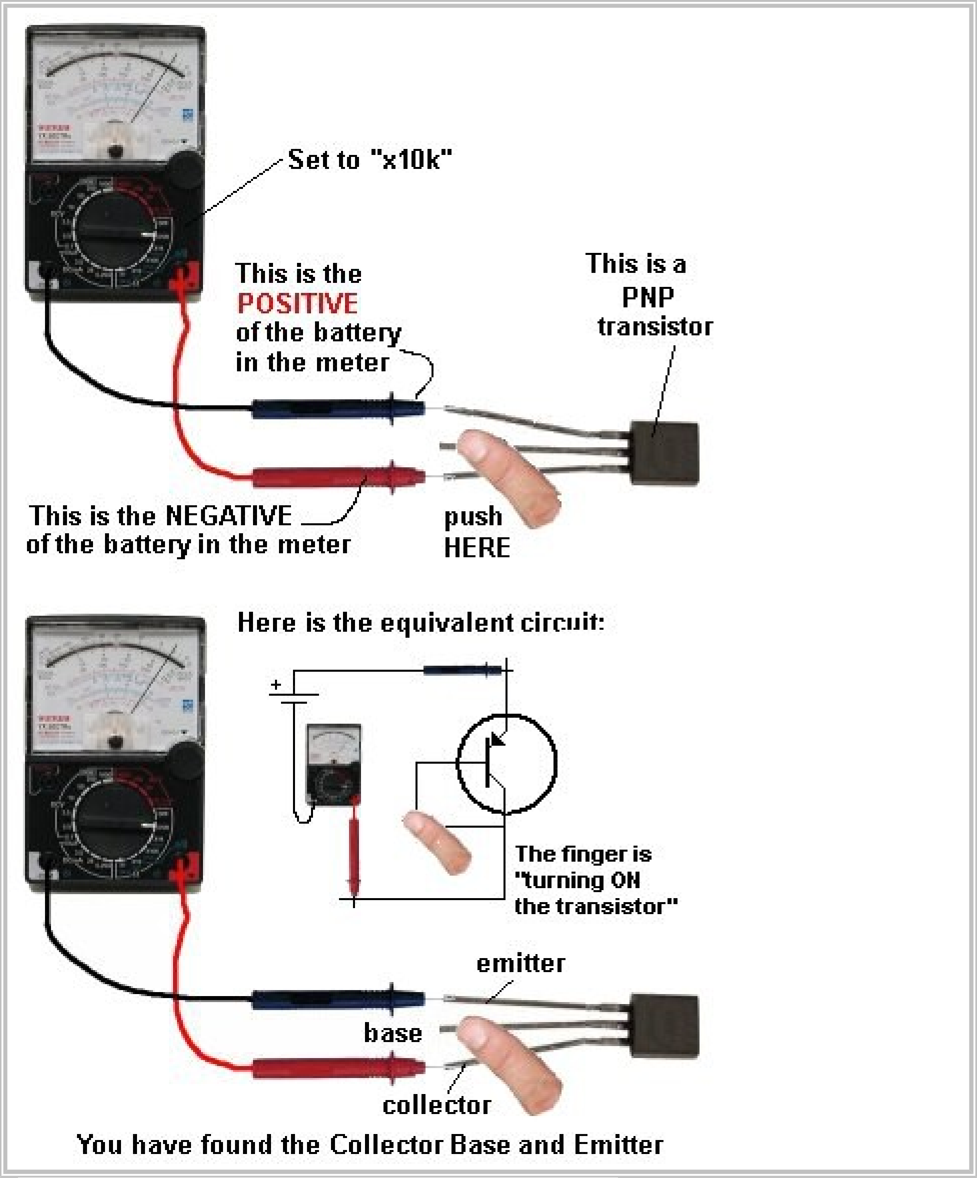
This is a PNP transistor
The red probe is the BASE

Step 2 - FINDING THE COLLECTOR and EMITTER

Set the meter to "x10k."
For an NPN transistor, place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.

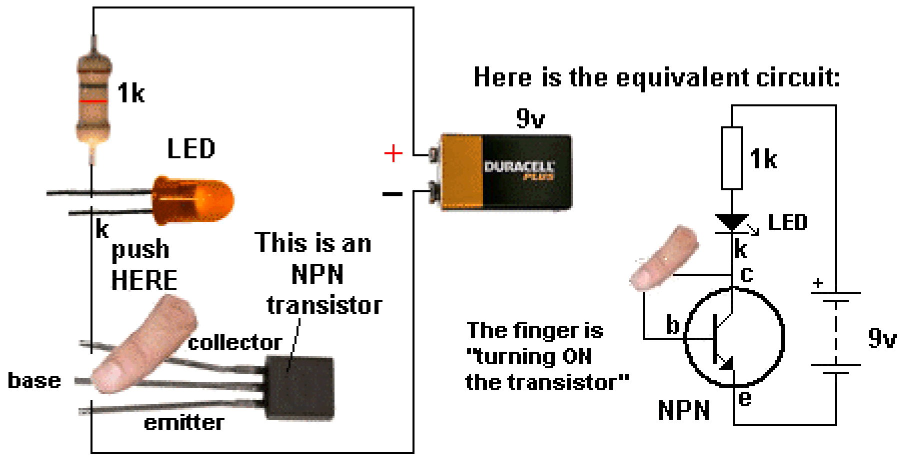


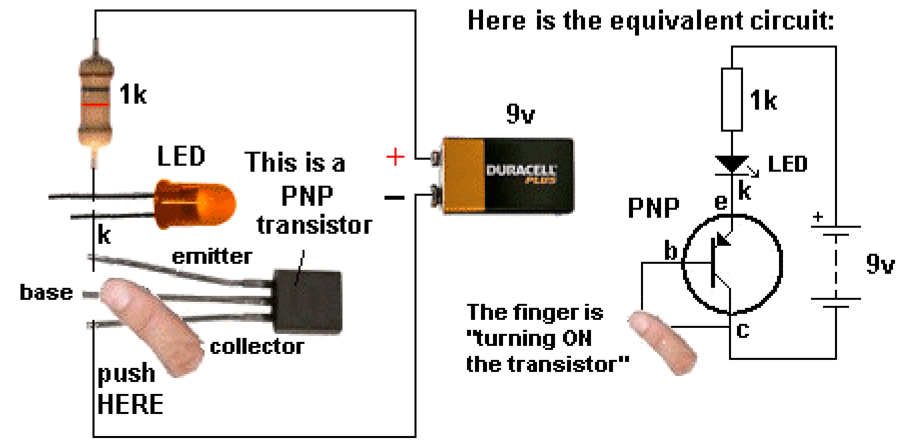
For a PNP transistor, **set the meter to "x10k"** place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.



SIMPLEST TRANSISTOR TESTER

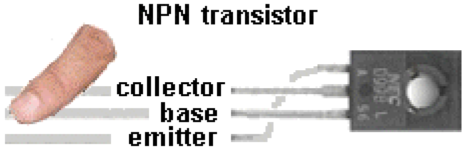
The simplest transistor tester uses a 9v battery, 1k resistor and a LED (any colour). Keep trying a transistor in all different combinations until you get one of the circuits below. When you push on the two leads, the LED will get brighter. The transistor will be NPN or PNP and the leads will be identified:





The leads of some transistors will need to be bent so the pins are in the same positions as shown in the diagrams. This helps you see how the transistor is being turned on. This works with NPN, PNP and Darlington transistors.

NPN transistor

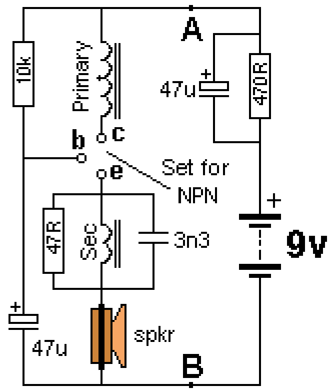


NPN transistor

TRANSISTOR TESTER - 1

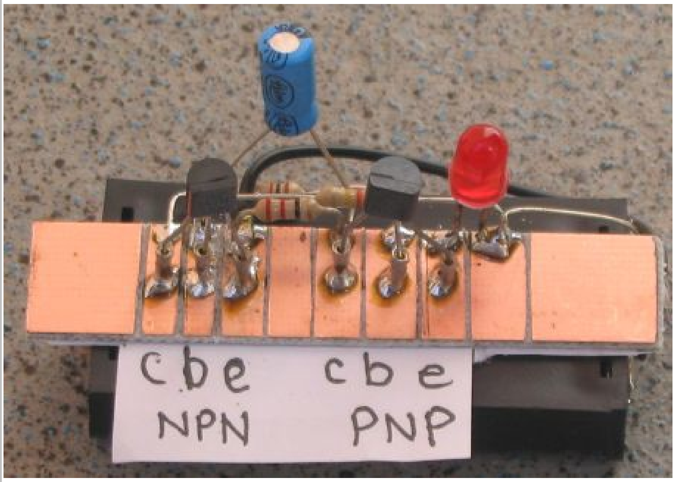
Transistor Tester - 1 project will test all types of transistors including Darlington and power. The circuit is set to test NPN types. To test PNP types, connect the 9v battery around the other way at points A and B.

The transformer in the photo is a 10mH choke with 150 turns of 0.01mm wire wound over the 10mH winding. The two original pins (with the red and black leads) go to the primary winding and the fine wires are called the Sec.
Connect the transformer either way in the circuit and if it does not work, reverse either the primary or secondary (but not both).
Almost any transformer will work and any speaker will be suitable.
If you use the speaker transformer described in the **Home Made Speaker Transformer** article, use one-side of the primary.



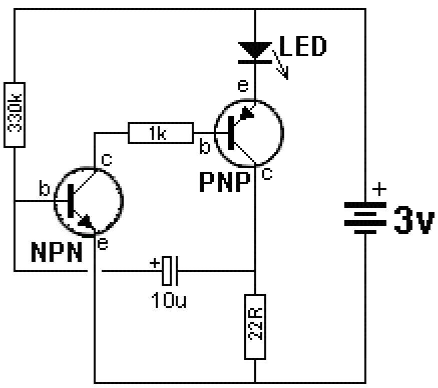
TRANSISTOR TESTER-1 CIRCUIT

The 10mH choke with 150 turns for the secondary



TRANSISTOR TESTER - 2

Here is another transistor tester.

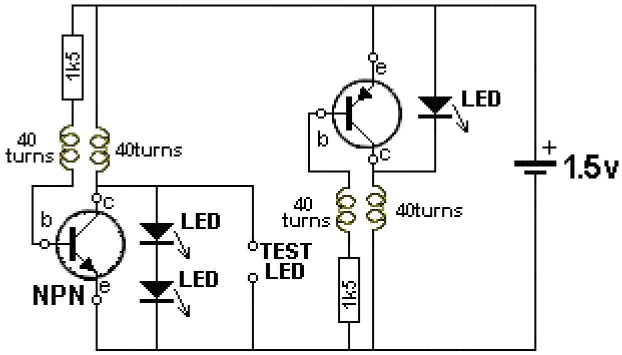


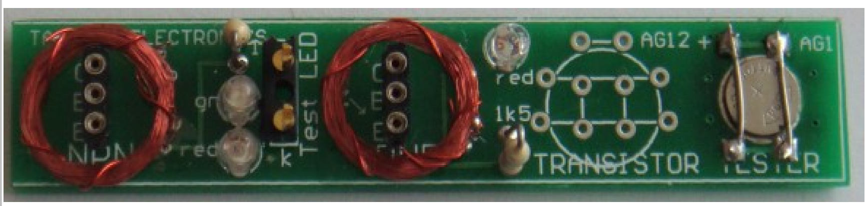
This is basically a high gain amplifier with feedback that causes the LED to flash at a rate determined by the 10u and 330k resistor.
Remove one of the transistors and insert the unknown transistor. When it is NPN with the pins as shown in the photo, the LED will flash. To turn the unit off, remove one of the transistors.

TRANSISTOR and LED TESTER - 3

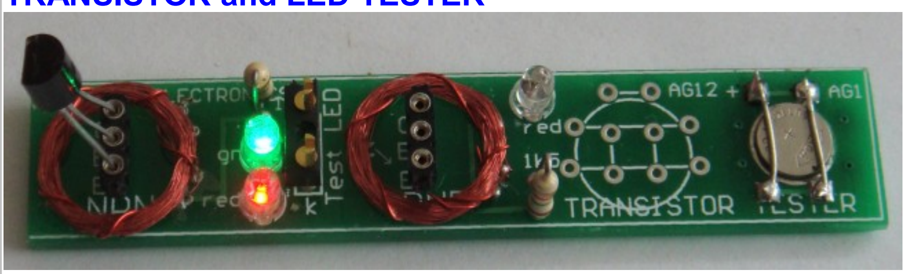
Here is another transistor tester. And it also tests LEDs. See the full project: **Transistor Tester**

This circuit is basically a Joule Thief design with the coil (actually a transformer) increasing the 1.5v supply to a higher voltage to illuminate one or two LEDs in series. The "LED Test" terminals uses the full voltage produced by the circuit and it will test any colour LED including a white LED. The two "coils" are wound on a 10mm dia pen with 0.1mm wire (very fine wire). All the components fit on a small PC board. A kit of parts for the project is a available from Talking Electronics for $4.00 plus $3.00 postage.





TRANSISTOR and LED TESTER



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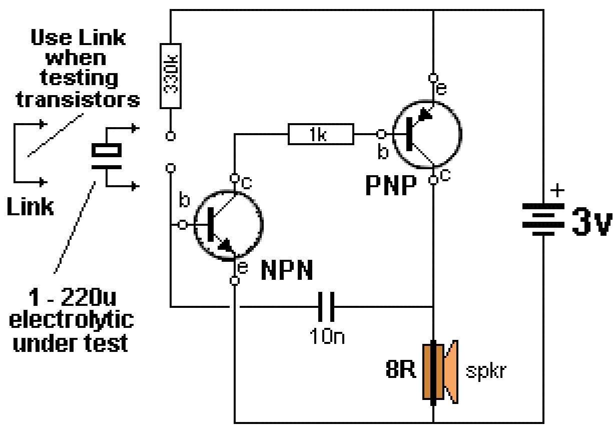
TRANSISTOR TESTER - 4 with ELECTROLYTIC TESTER

This circuit will test transistors and electrolytic capacitors from 1u to 220u for leakage, open, shorts and approx capacitance.

Build the circuit on a strip of PC board as shown in **Transistor Tester-2** so the transistors can be replaced with a suspect transistor and an electrolytic can be fitted in place of the link for the capacitor.

When an electrolytic is fitted to the circuit, it will produce a wailing and eventually stop. If the tone continues, the electrolytic is leaky.

If the tone is not produced, the electrolytic is open. If the tone does not change, the electrolytic is shorted.



TRANSISTOR TESTER - 4 CIRCUIT

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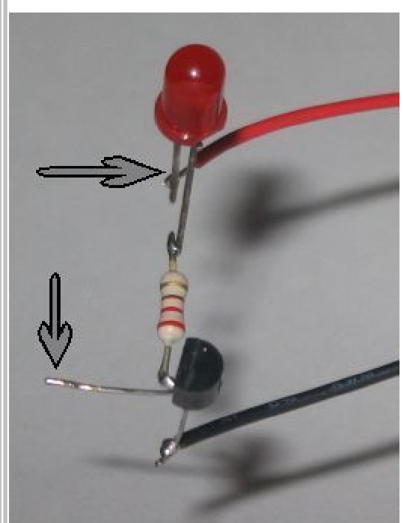
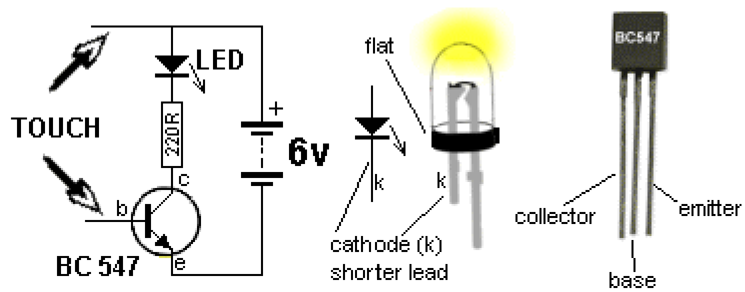


WORLDS SIMPLEST CIRCUIT

This is the simplest circuit you can get. Any NPN transistor can be used.



Connect the LED, 220 ohm resistor and transistor as shown in the photo.
Touch the top point with two fingers of one hand and the lower point with
fingers of the other hand and squeeze.
The LED will turn on brighter when you squeeze harder.

Your body has resistance and when a voltage is present, current will flow though your body (fingers). The transistor is amplifying the current through your fingers about 200 times and this is enough to illuminate the LED.

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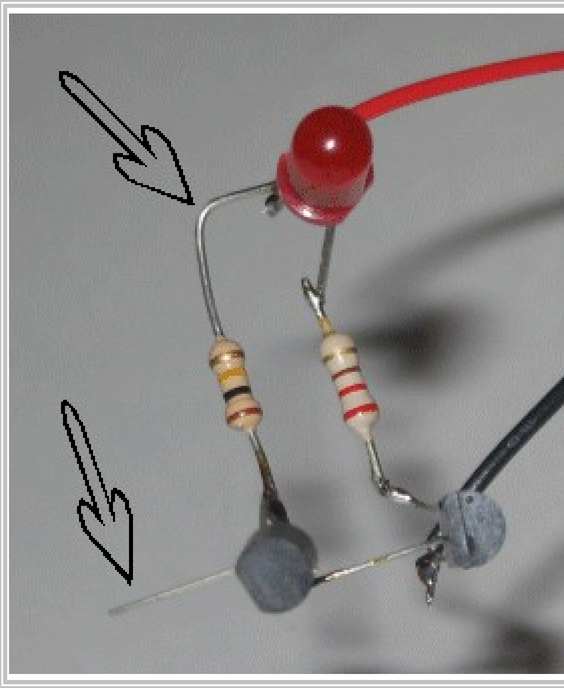
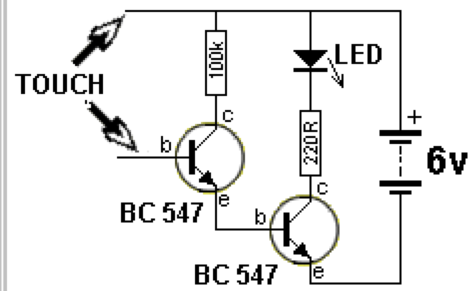
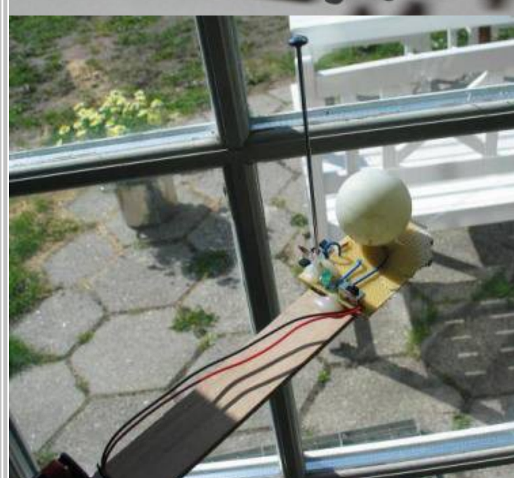


SECOND SIMPLEST CIRCUIT

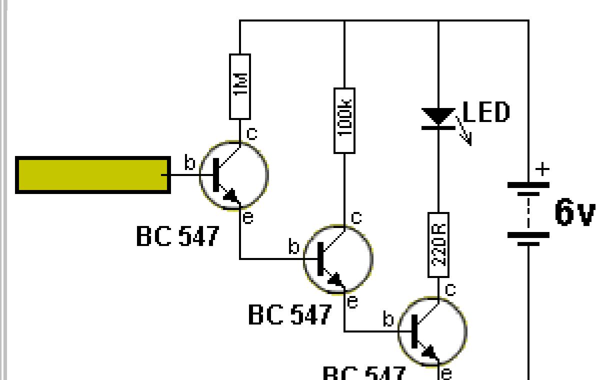


This the second simplest circuit in the world. A second transistor has been added in place of your fingers. This transistor has a gain of about 200 and when you touch the points shown on the diagram, the LED will illuminate with the slightest touch. The transistor has amplified the current (through your fingers) about 200 times.



8 MILLION GAIN!

This circuit is so sensitive it will detect "mains hum." Simply move it across any wall and it will detect where the mains cable is located. It has a gain of about 200 x 200 x 200 = 8,000,000 and will also detect static electricity and the presence of your hand without any direct contact. You will be amazed what it detects! There is static electricity EVERYWHERE! The input of this circuit is classified as very high impedance.

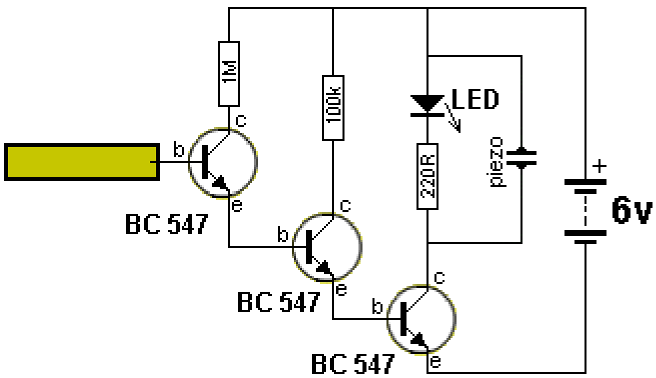


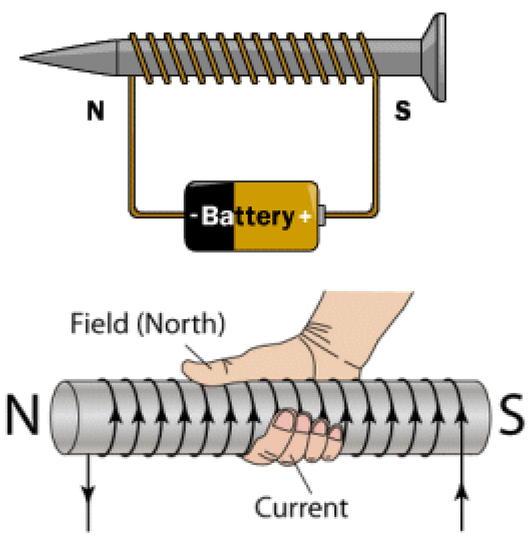
Here is a photo of the circuit, produced by a constructor, where he claimed he detected "ghosts."

http://letsmakerobots.com/node/12034
http://letsmakerobots.com/node/18933

MAINS HUM DETECTOR

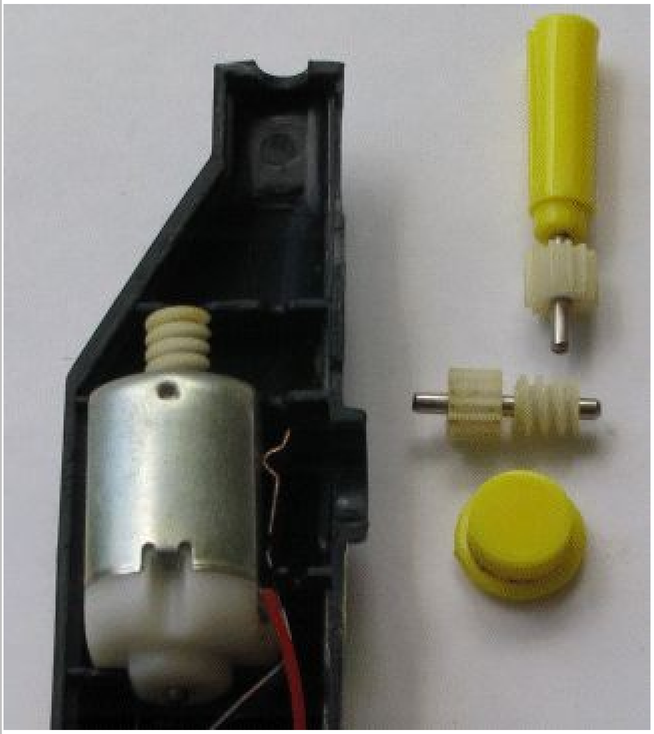
This simple circuit will detect if a cable is carrying the "Mains." The piezo diaphragm is will let you hear the hum: **Do not touch** the copper wire. Only place the detector **near** the plastic covering. It will work at 2cm from the cable.





FINDING THE NORTH POLE

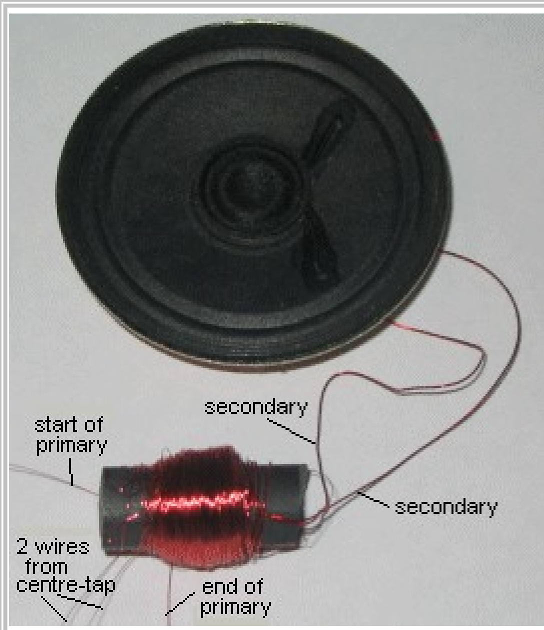
The diagrams show that a North Pole will be produced when the positive of a battery is connected to wire wound in the direction shown. This is Flemmings **Right Hand Rule** and applies to motors, solenoids and coils and anything wound like the turns in the diagram.

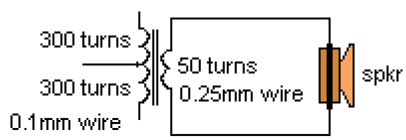


A two-worm reduction gearbox producing a reduction of 12:1 and 12:1 = 144:1 The gears are in the correct positions to produce the reduction.

BOXES FOR PROJECTS

One of the most difficult things to find is a box for a project. Look in your local "junk" shop, $2.00 shop, fishing shop, and toy shop. And in the medical section, for handy boxes. It's surprising where you will find an ideal box.
The photo shows a suitable box for a Logic Probe or other design. It is a toothbrush box. The egg shaped box holds "Tic Tac" mouth sweeteners and the two worm reduction twists a "Chuppa Chub." It cost less than $4.00 and the equivalent reduction in a hobby shop costs up to $16.00!

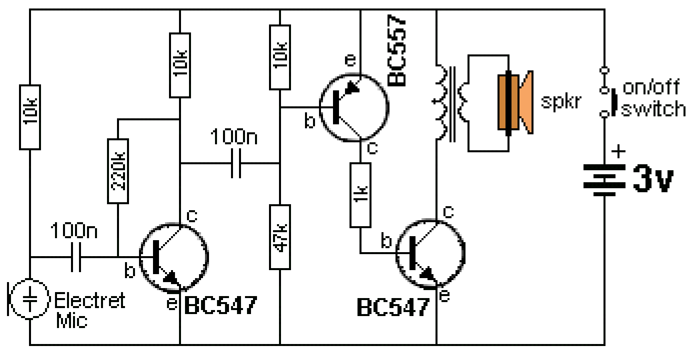




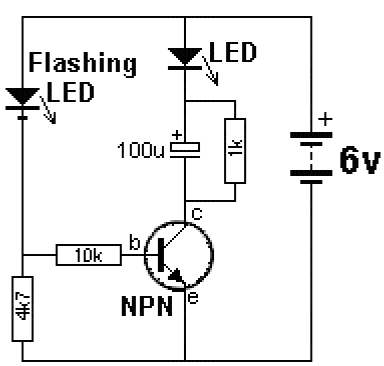
HOME MADE SPEAKER TRANSFORMER

The **speaker transformer** is made by winding 50 turns of 0.25mm wire on a small length of 10mm dia ferrite rod.
The size and length of the rod does not matter - it is just the number of turns that makes the transformer work. This is called the secondary winding.
The primary winding is made by winding 300 turns of 0.1mm wire (this is very fine wire) over the secondary and ending with a loop of wire we call the centre tap.
Wind another 300 turns and this completes the transformer.
It does not matter which end of the

secondary is connected to the top of the speaker.
It does not matter which end of the primary is connected to the collector of the transistor in the circuits in this book.



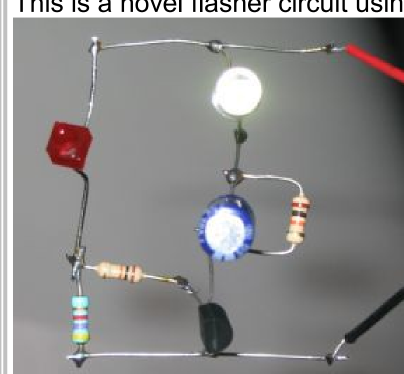
transistor is set for 3v supply. The second and third transistors are not turned on during idle conditions and the quiescent current is just 5mA.
The project is ideal for listening to conversations or TV etc in another room with long leads connecting the microphone to the amplifier.



The circuit uses a flashing LED to flash a super-bright 20,000mcd white LED

LED FLASHER WITH ONE TRANSISTOR!

This is a novel flasher circuit using a single driver transistor that takes its flash-rate from a flashing LED. The flasher in the photo is 3mm. An ordinary LED will not work.

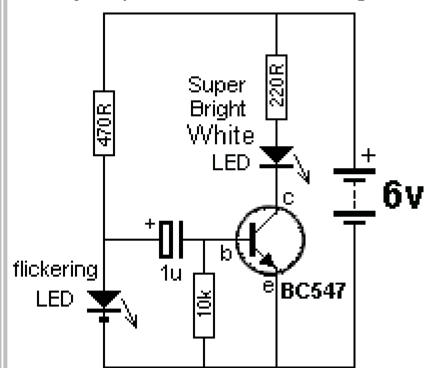


The flash rate cannot be altered by the brightness of the high-bright white LED can be adjusted by altering the 1k resistor across the 100u electrolytic to 4k7 or 10k.
The 1k resistor discharges the 100u so that when the transistor turns on, the charging current into the 100u illuminates the white LED.
If a 10k discharge resistor is used, the 100u is not fully

	discharged and the LED does not flash as bright. All the parts in the photo are in the same places as in the circuit diagram to make it easy to see how the parts are connected.

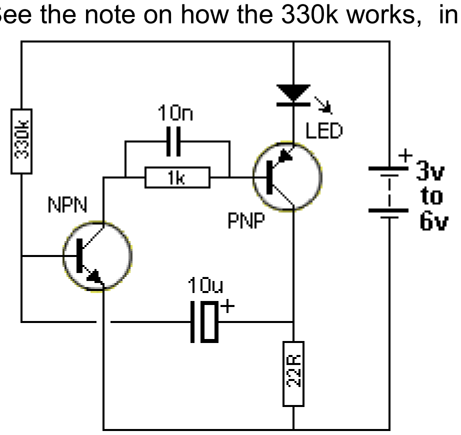
Arc Welder Simulator **for Model Railways**

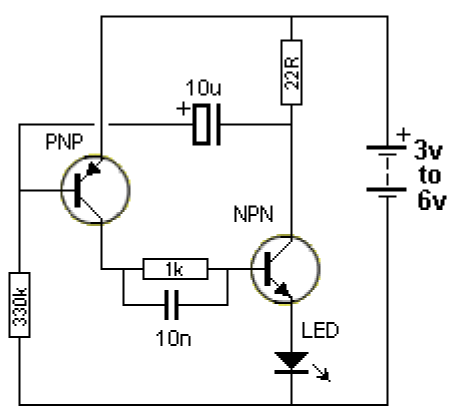
This very simple circuit replaces a very complex circuit (one of our previous projects) because all the random flashing is done via a microscopic microcontroller inside the flickering LED.
These LEDs can be purchased on eBay and you can contact Colin Mitchell for the link.
The super-bright white LED flashes much more than the flickering LED because the transistor and the 1u electrolytic picks up the pulses (the waveform) across the 470R resistor and only the main changes in the signal are transferred to the white LED. The 10k is very important as it discharges the 1u to help produce the OFF portion of the waveform.



LED FLASHER

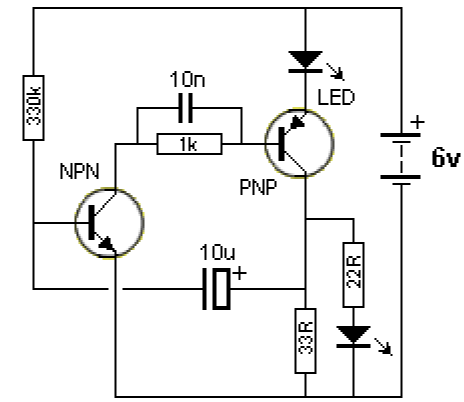
These two circuits will flash a LED very bright and consume less than 2mA average current. Both circuits can use a transistor with a larger current capability for the second transistor. The first circuit needs a PNP transistor and the second circuit needs an NPN transistor if a number of LEDs need to be driven. The second circuit is the basis for a simple motor speed control.
See the note on how the 330k works, in **Flashing Two LEDs** below.

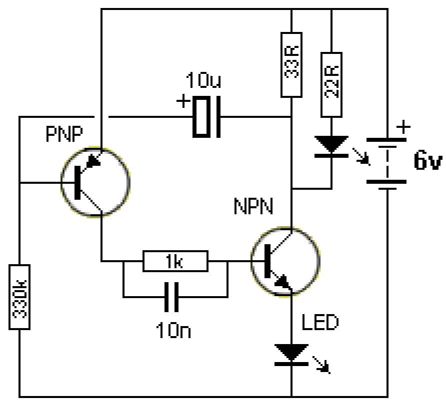


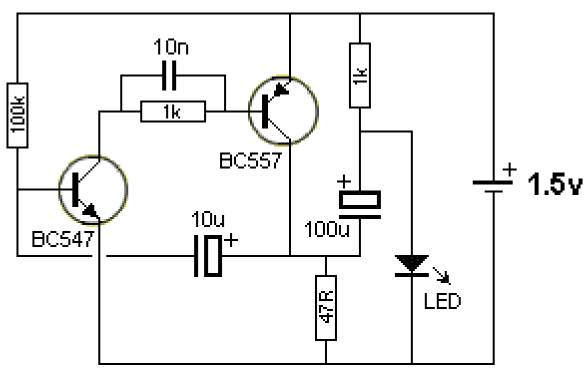


FLASHING TWO LEDS

These two circuits will flash two LEDs very bright and consume less than 2mA average current. They require 6v supply. The 330k may need to be 470k to produce flashing on 6v as 330k turns on the first transistor too much and the 10u does not turn the first transistor off a small amount when it becomes fully charged and thus cycling is not produced.







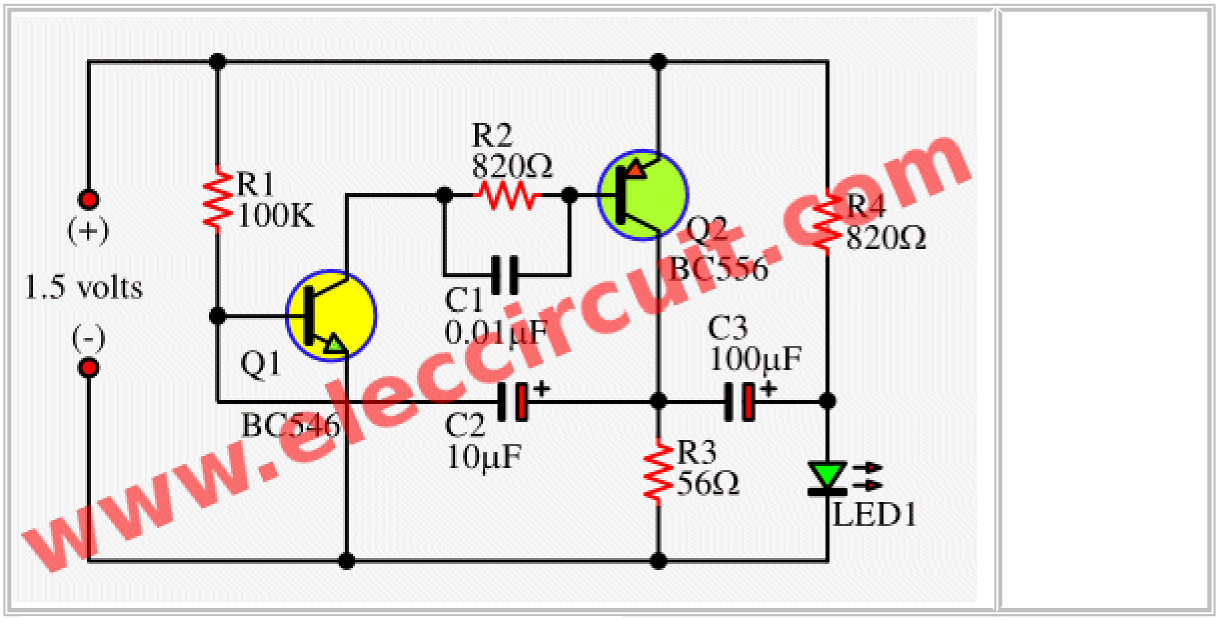
1.5v LED FLASHER

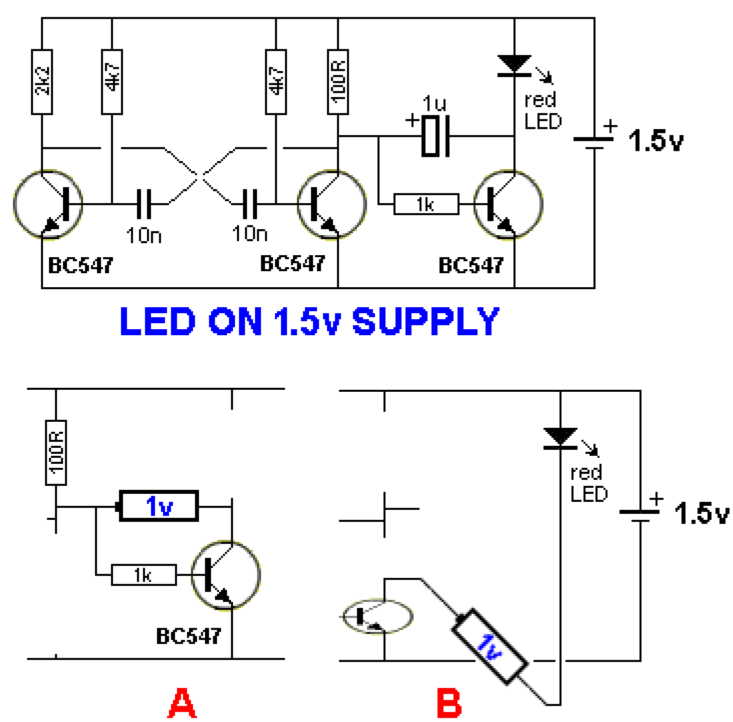
Here is my circuit copied by Eleccircuit.com:

1.5v LED FLASHER

This will flash a LED, using a single 1.5v cell. It may even flash a white LED even though this type of LED needs about 3.2v to 3.6v for operation.
The circuit takes about 2mA but produces a very bright flash.

My circuit has been copied by Eleccircuit.com but my layout makes it much easier to see how the circuit works.





LED on 1.5v SUPPLY

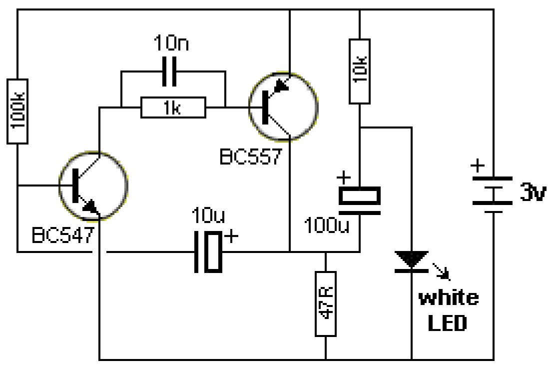
A red LED requires about 1.7v before it will start to illuminate - below this voltage - NOTHING! This circuit takes about 12mA to illuminate a red LED using a single cell, but the interesting feature is the way the LED is illuminated.

The 1u electrolytic can be considered to be a 1v cell.

(If you want to be technical: it charges to about 1.5v - 0.2v loss due to collector-emitter = 1.3v and a lost of about 0.2v via collector-emitter in diagram B.)

It is firstly charged by the 100R resistor and the 3rd transistor (when it is fully turned ON via the 1k base resistor). This is shown in diagram "A." During this time the second transistor is not turned on and that's why we have omitted it from the diagram. When the second transistor is turned ON, the 1v cell is pulled to the 0v rail and the negative of the cell is actually 1v below the 0v rail as shown in diagram "B."

The LED sees 1.5v from the battery and about 1v from the electrolytic and this is sufficient to illuminate it. Follow the two voltages to see how they add to 2.5v.



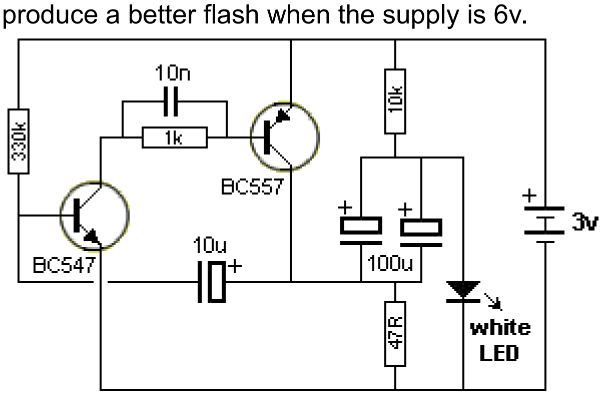
3v WHITE LED FLASHER

3v WHITE LED FLASHER

This will flash a white LED, on 3v supply and produce **a very bright flash.** The circuit produces a voltage higher than 5v if the LED is not in circuit but the LED limits the voltage to its characteristic voltage of 3.2v to 3.6v. The circuit takes about 2mA an is actually a voltage-doubler (voltage incrementer) arrangement. Note the 10k charges the 100u. It does not illuminate the LED because the 100u is charging and the voltage across it is always less than 3v. When the two transistors conduct, the collector of the BC557 rises to rail voltage and pulls the 100u HIGH. The negative of the 100u effectively sits just below the positive rail and the positive of the electro is about 2v higher than this. All the energy in the electro is pumped into the LED to produce a very bright flash.

BRIGHT FLASH FROM FLAT BATTERY

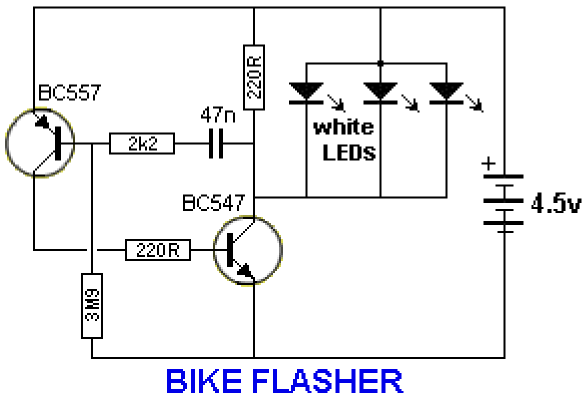
This circuit will flash a white LED, on a supply from 2v to 6v and produce a very bright flash. The circuit takes about 2mA and old cells can be used. The two 100u electros in parallel produce a better flash when the supply is 6v.



WHITE LED FLASHER

BIKE FLASHER

This circuit will flash a white LED (or 2,3 4 LEDs in parallel) at 2.7Hz, suitable for the rear light on a bike.



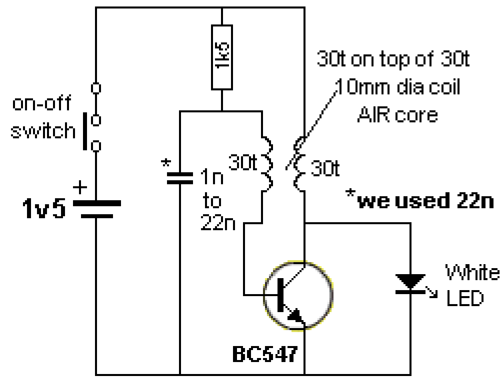
BIKE FLASHER - Amazing!

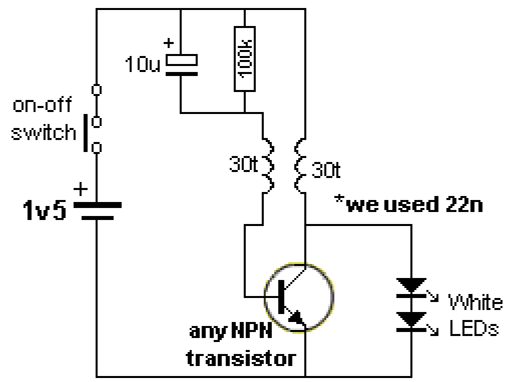
This bike flasher uses a single transistor to flash two white LEDs from a single cell. And it has **no core** for the transformer - just AIR!

All **Joule Thief** circuits you have seen, use a ferrite rod or toroid (doughnut) core and the turns are wound on the ferrite material. But this circuit proves the collapsing magnetic flux produces an increased voltage, even when the core is AIR. The fact is this: When a magnetic filed collapses quickly, it produces a higher voltage in the opposite direction and in this case the magnetic field surrounding the coil is sufficient to produce the energy we need.

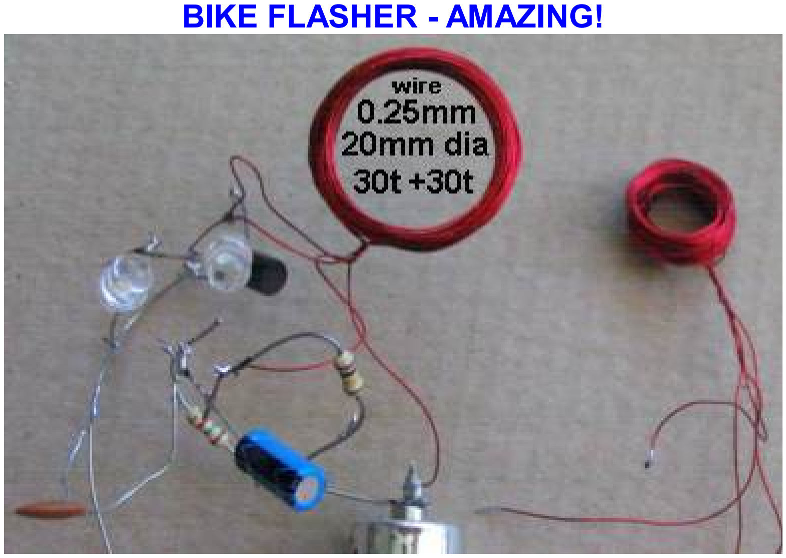
Wind 30 turns on 10mm (1/2" dia) pen or screwdriver and then another 30 turns on top. Build the first circuit and connect the wires. You can use 1 or two LEDs. If the circuit does not work, swap the wires going to the base.

Now add the 10u electrolytic and 100k resistor (remove the 1k5). The circuit will now flash. You must use 2 LEDs for the flashing circuit.





BIKE FLASHER - AMAZING!

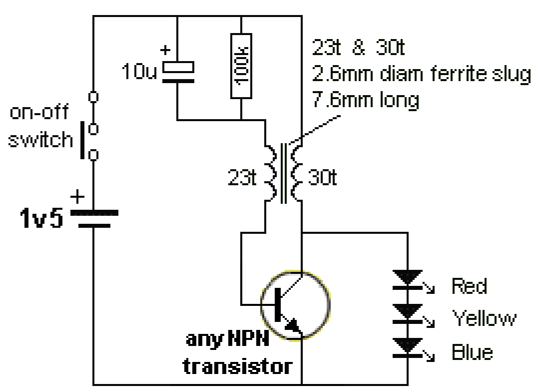


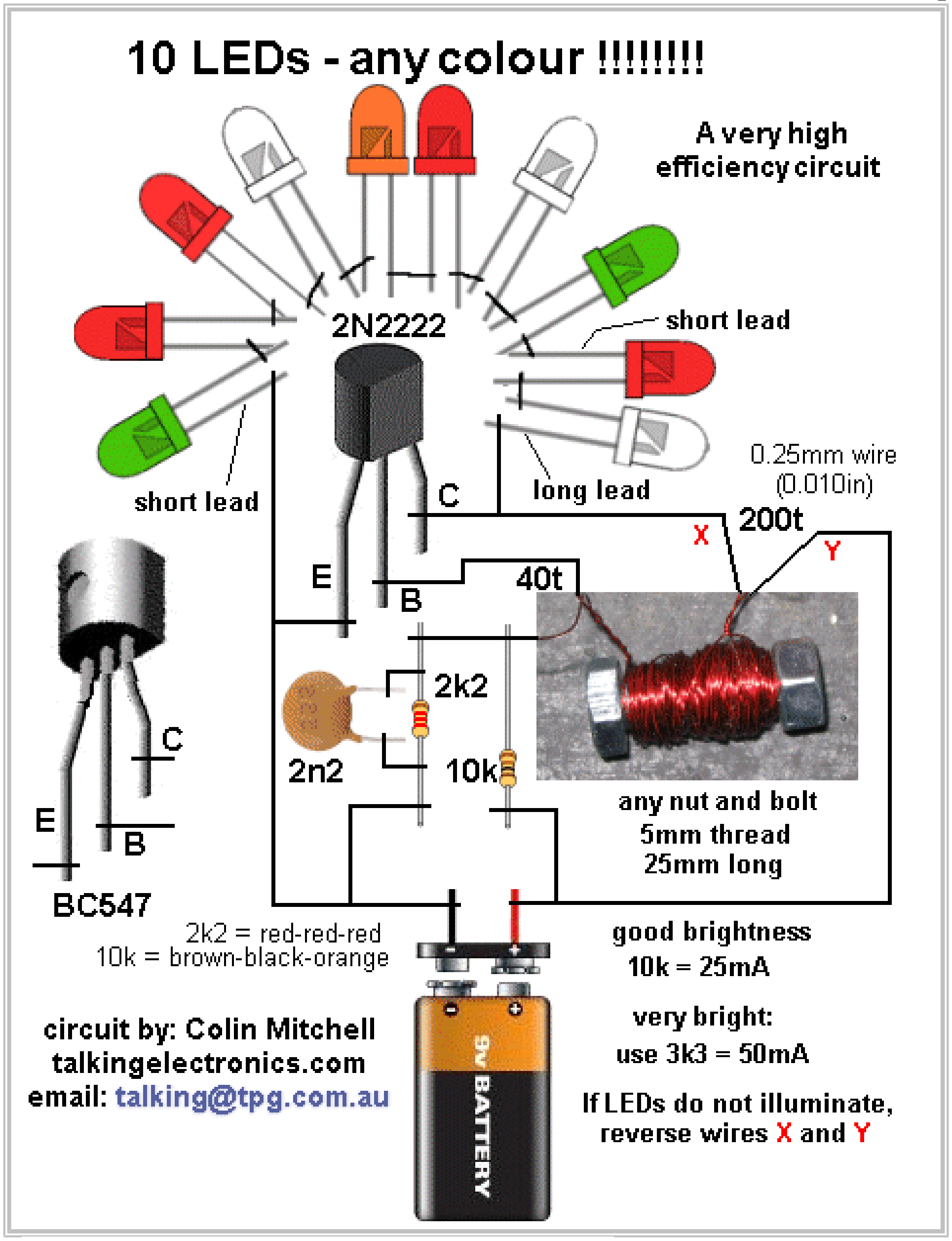
THE IMPROVED BIKE FLASHER CIRCUIT

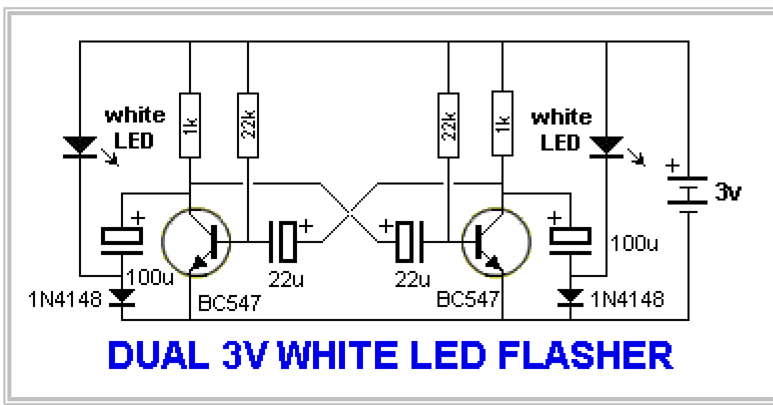
The original 30 turns + 30 turns coil is shown on the right. The circuit took 20mA to illuminate two LEDs.
The secret to getting the maximum energy from the coil (to flash the LEDs) is the maximum amount of air in the centre of the coil. Air cannot transfer a high magnetic flux (density) so we provide a large area (volume) of low flux (density) to provide the energy. The larger (20mm) coil reduced the current from 20mA to 11mA for the same brightness. This could be improved further but the coil gets too big. The two 30-turn windings must

be kept together because the flux from the main winding must cut the feedback winding to turn ON the transistor **HARD**.
When the transistor starts to turn on via the 100k, it creates magnetic flux in the main winding that cuts the feedback winding and a positive voltage comes out the end connected to the base and a negative voltage comes out the end connected to the 100k and 10u. This turns the transistor ON more and it continues to turn ON until fully turned ON. At this point the magnetic flux is not expanding and the voltage does not appear in the feedback winding.
During this time the 10u has charged and the voltage on the negative lead has dropped to a lower voltage than before. This effectively turns OFF the transistor and the current in the main winding ceases abruptly. The magnetic flux collapses and produces a voltage in the opposite direction that is higher than the supply and this is why the two LEDs illuminate. This also puts a voltage through the feedback winding that keeps the transistor OFF. When the magnetic flux has collapsed, the voltage on the negative lead of the 10u is so low that the transistor does not turn on. The 100k discharges the 10u and the voltage on the base rises to start the next cycle.
You can see the 100k and 1k5 resistors and all the other parts in a "birds nest" (in the photo above), to allow easy experimenting.
This is the first circuit you should build to flash a white LED from a single cell.
It covers many features and shows how the efficiency of a LED increases when it is pulsed very briefly with a high current.
The two coils form a TRANSFORMER and show how a collapsing magnetic field produces a high voltage (we use 6v of this high voltage).
The 10u and 100k form a delay circuit to produce the flashing effect.
You can now go to all the other **Joule Thief** circuits and see how they "missed the boat" by not experimenting fully to simply their circuits. That's why a "birds nest" arrangement is essential to encourage experimenting.
Note: Changing the turns to 40t for the main winding and 20t for the feedback (keeping the turns tightly wound together by winding wire around them) reduced the current to 8-9mA.

The circuit can be made small by using a ferrite slug 2.6mm diam x 7.6mm long.
The inductance of this transformer is quite critical and the voltage across the LEDs must be over 6v for the circuit to work. It will not work with one or two LEDs. It needs THREE LEDs !!!
If the author not not keep experimenting, he would have missed this amazing feature !!







DUAL 3v WHITE LED FLASHER

This circuit alternately flashes two white LEDs, on a 3v supply and produces a **very bright flash.** The circuit produces a voltage higher than 5v if the LED is not in circuit but the LED limits the voltage to its characteristic voltage of 3.2v

to 3.6v. The circuit takes about 2mA and is actually a voltage-doubler (voltage incrementer) arrangement. The 1k charges the 100u and the diode drops 0.6v to prevent the LED from starting to illuminate on 3v. When a transistor conducts, the collector pulls the 100u down towards the 0v rail and the negative of the electro is actually about 2v below the 0v rail. The LED sees 3v + 2v and illuminates very brightly when the voltage reaches about 3.4v. All the energy in the electro is pumped into the LED to produce a very bright flash.

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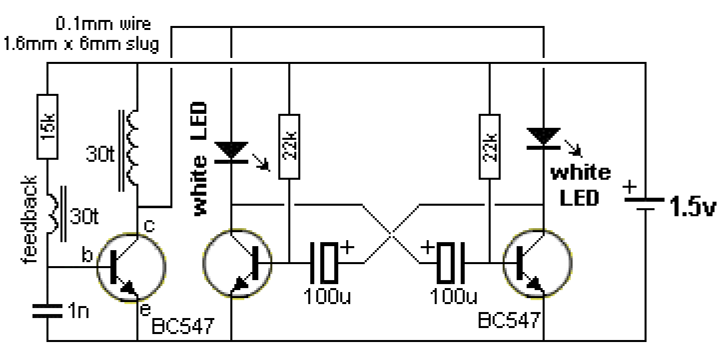

DUAL 1.5v WHITE LED FLASHER

DUAL 1v5 WHITE LED FLASHER

This circuit alternately flashes two white LEDs, on a 1.5v supply and produces a **very bright flash.** The circuit produces a voltage of about 25v when the LEDs are not connected, but the LEDs reduce this as they have a characteristic voltage-drop across them when they are illuminated. Do not use a supply voltage higher than 1.5v. The circuit takes about 10mA.

The transformer consists of 30 turns of very fine wire on a 1.6mm slug 6mm long, but any ferrite bead or slug can be used. The number of turns is not critical.

The 1n is important and using any other value or connecting it to the positive line will increase the supply current.

Using LEDs other than white will alter the flash-rate considerably and both LEDs must be the same colour.

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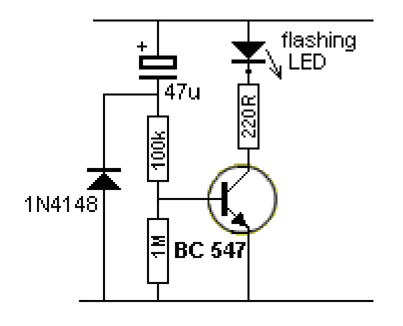

LED FLASHES 3 TIMES WHEN POWER IS APPLIED

This circuits uses a FLASHING LED - not an ordinary LED.
When the circuit turns ON, the electrolytic is uncharged and the charging-current turns on the transistor. This makes the LED flash.
The value of the 47u and 100k will depend on how many times you want the LED to flash.
The 1N4148 diode discharges the electrolytic when the power is turned off so the circuit will start immediately the power is applied.
This diode is not needed if the circuit is turned off for a long time.

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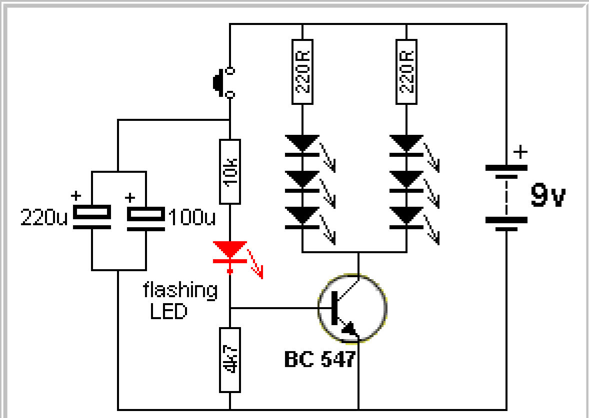

LED FLASHES FOR 5 SECONDS AFTER BUTTON IS RELEASED

This circuits uses a FLASHING LED - not an ordinary LED.
When the switch is pressed, the LEDs flash for about 5 seconds when the switch is released. and turn off.
The circuit takes NO CURRENT after the LEDs have turned OFF.
You can experiment with the value of the electrolytics, the 4k7 and 10k to get the result you want. Use red or green LEDs. Only 2 white LEDs can used in each string for 9v supply

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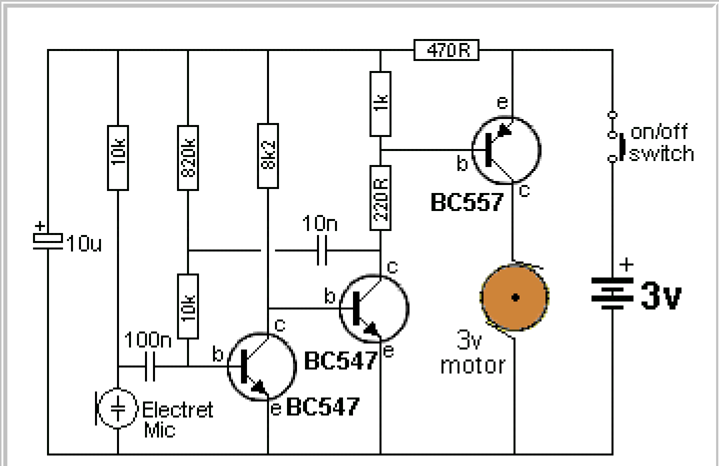

DANCING FLOWER

This circuit was taken from a dancing flower.
A motor at the base of the flower had a shaft up the stem and when the microphone detected music, the bent shaft made the flower wiggle and move.
The circuit will respond to a whistle, music or noise.

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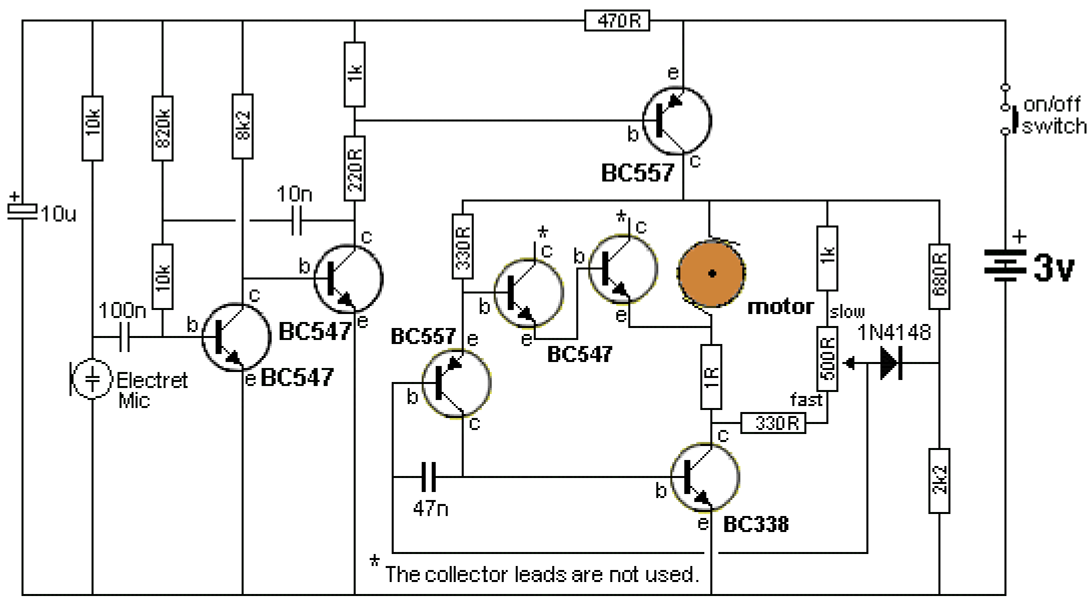

DANCING FLOWER with SPEED CONTROL

The **Dancing Flower** circuit can be combined with the **Motor Speed Control** circuit to produce a requirement from one of the readers.

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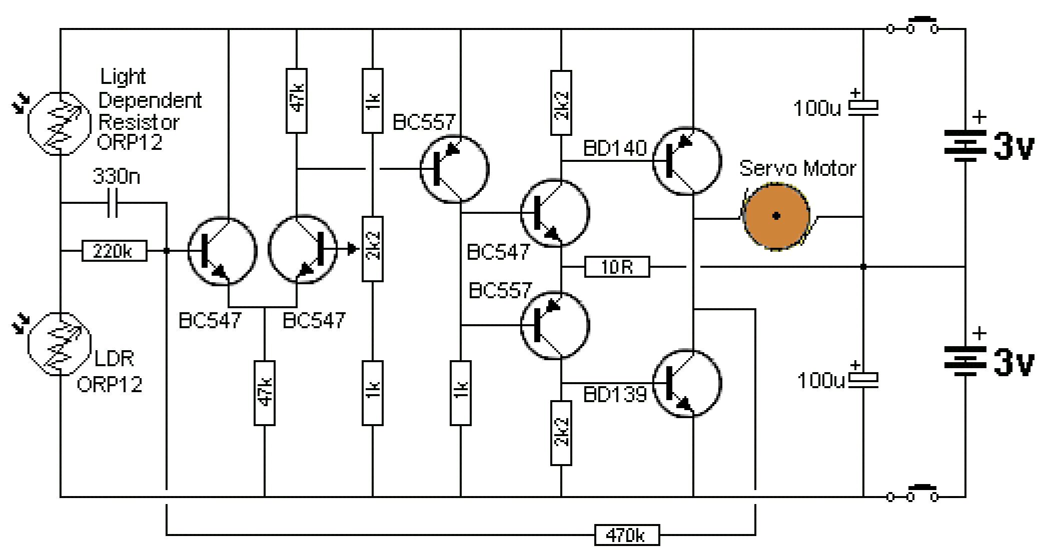

WHITE LINE FOLLOWER

This circuit can be used for a toy car to follow a white line. The motor is either a 3v type with gearing to steer the car or a rotary actuator or a servo motor. When equal light is detected by the photo resistors the voltage on the base of the first transistor will be mid rail and the circuit is adjusted via the 2k2 pot so the motor does not receive any voltage. When one of the LDR's receives more (or less) light, the motor is activated. And the same thing happens when the other LDR receives less or more light.

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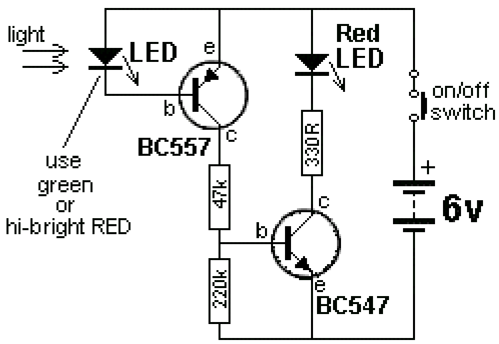

LED DETECTS LIGHT

All LEDs give off light of a particular colour but some LEDs are also able to detect light. Obviously they are not as good as a device that has been specially made to detect light; such as solar cell, photocell, photo resistor, light dependent resistor, photo transistor, photo diode and other photo sensitive devices.
A green LED will detect light and a high-bright red LED will respond about 100 times better than a green LED, but the LED in this position in the circuit is classified as very high impedance and it requires a considerable amount of amplification to turn the detection into a worthwhile current-source.
All other LEDs respond very poorly and are not worth trying.
The accompanying circuit amplifies the output of the LED and enables it to be used for a number of applications.
The LED only responds when the light enters the end of the LED and this makes it ideal for solar trackers and any time there is a large difference between the dark and light conditions. It will not detect the light in a room unless the lamp is very close.

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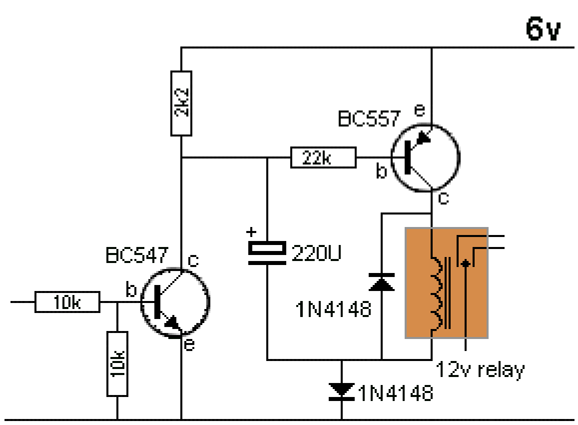


12v RELAY ON 6V SUPPLY

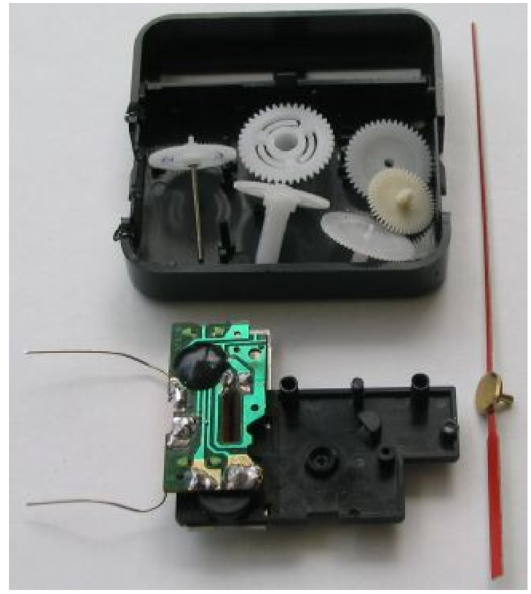
This circuit allows a 12v relay to operate on a 6v or 9v supply. Most 12v relays need about 12v to "pull-in" but will "hold" on about 6v. The 220u charges via the 2k2 and bottom diode. When an input above 1.5v is applied to the input of the circuit, both transistors are turned ON and the 5v across the electrolytic causes the negative end of the electro to go below the 0v rail by about 4.5v and this puts about 10v across the relay.

Alternatively you can rewind a 12v relay by removing about half the turns.
Join up what is left to the terminals. Replace the turns you took off, by connecting them in parallel with the original half, making sure the turns go the same way around

-

MAKE TIME FLY!

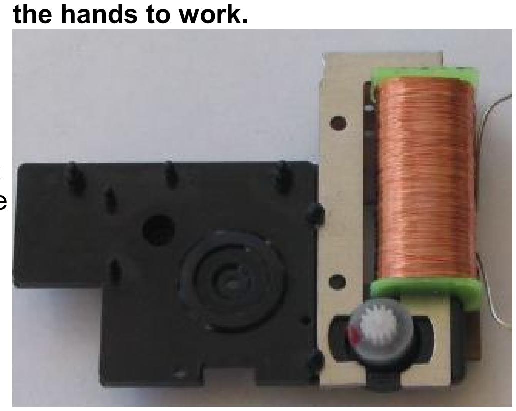
Connect this circuit to an old electronic clock mechanism and speed up the motor 100 times!
The "motor" is a simple "stepper-motor" that performs a half-rotation each time the electromagnet is energised. It normally takes 2 seconds for one revolution. But our circuit is connected directly to the winding and the frequency can be adjusted via the pot.
Take the mechanism apart, remove the 32kHz crystal and cut one track to the electromagnet. Connect the circuit below via wires and re-assemble the clock.
As you adjust the pot, the "seconds hand" will move clockwise or anticlockwise and you can watch the hours "fly by" or make "time go backwards."
The multivibrator section needs strong buffering to drive the 2,800 ohm inductive winding of the motor and that's why push-pull outputs have been used. The flip-flop circuit cannot drive the highly inductive load directly (it upsets the waveform enormously).
From a 6v supply, the motor only gets about 4v due to the voltage drops across the transistors. Consumption is about 5mA.



The crystal removed and a "cut track" to the coil. The 6 gears must be re-fitted for the hands to work.

HOW THE MOTOR WORKS

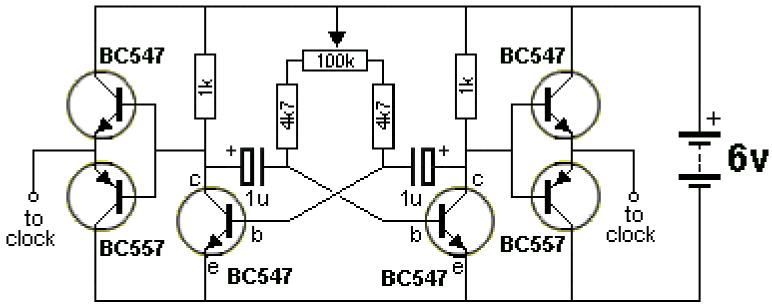
The rotor is a magnet with the north pole shown with the red mark and the south pole opposite.
The electromagnet actually produces poles. A strong North near the end of the electromagnet, and a weak North at the bottom. A strong South at the top left and weak South at bottom left. The rotor rests with its poles being attracted to the 4 pole-pieces equally.

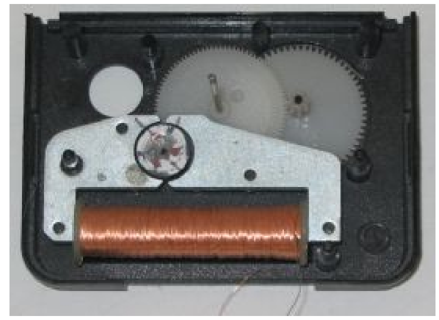


A close-up of the clock motor

Voltage must be applied to the electromagnet around the correct way so that repulsion occurs. Since the rotor is sitting equally between the North poles, for example, it will see a strong pushing force from the pole near the electromagnet and this is how the motor direction is determined. A reversal of voltage will revolve the rotor in the same direction as before. The design of the motor is much more complex than you think!!

Another clock motor is shown below. Note the pole faces spiral closer to the rotor to make it revolve in one direction. What a clever design!!





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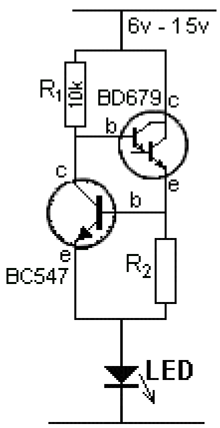
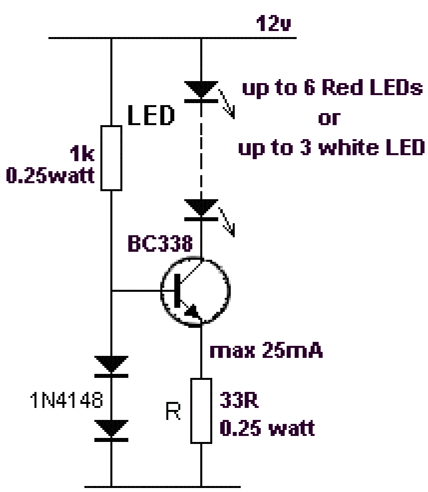


CONSTANT CURRENT SOURCE

This circuit provides a constant current to the LED. The LED can be replaced by any other component and the current through it will depend on the value of R2. Suppose R2 is 560R. When 1mA flows through R2, 0.56v will develop across this resistor and begin to turn on the BC547. This will rob the base of BD 679 with turn-on voltage and the transistor turns off slightly. If the supply voltage increases, this will try to increase the current through the circuit. If the current tries to increase, the voltage across R2 increases and the BD 679 turns off more and the additional voltage appears across the BD 679.
If R2 is 56R, the current through the circuit will be 10mA. If R2 is 5R6, the current through the circuit will be 100mA - although you cannot pass 100mA through a LED without damaging it.

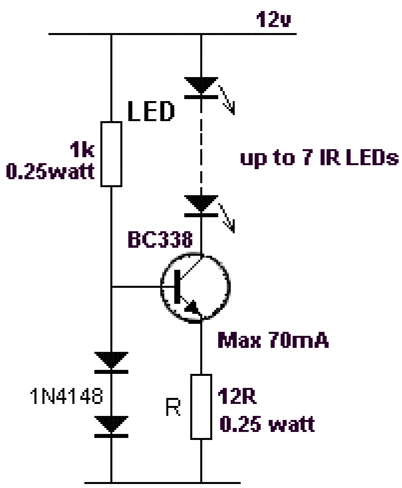
-



LED driver for 12v CAR

Here is a simple circuit that will drive any number of LEDs in a single string with a constant 25mA without having to work out the value of the dropper resistor. You can use up to 6 red LED or up to 3 white LEDs with the same circuit.
The supply can be 12v to 16v without the brightness altering.

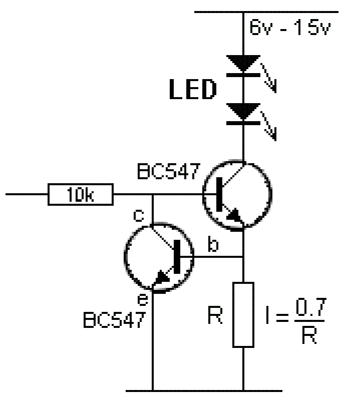
-

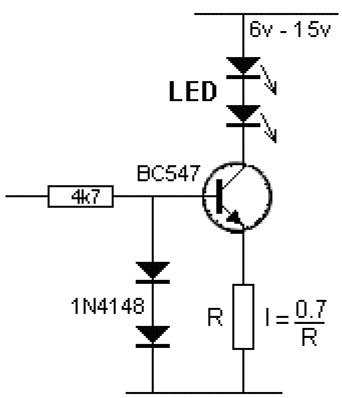


LED driver IR LEDs in a 12v CAR

This circuit will drive up to 7 IR LEDs at a constant current of 70mA from a 12v supply. These LEDs will illuminate ultra-violet sensitive paint to produce a white glow.

-

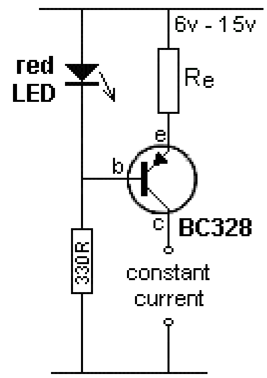


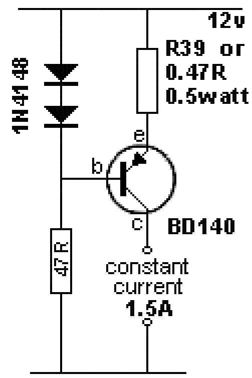


CONSTANT CURRENT SOURCE circuits 2 & 3

By rearranging the components in the circuit above, it can be designed to turn ON or OFF via an input.
The current through the LED (or LEDs) is determined by the value of R.
5mA   R = 120R or 150R
10mA R = 68R
15mA   R = 47R
20mA R = 33R
25mA   R = 22R or 33R
30mA R = 22R

-

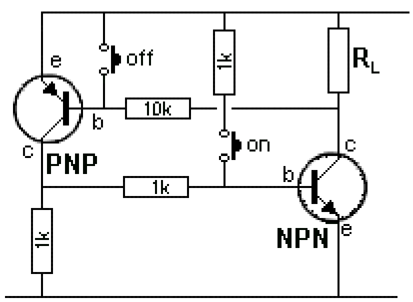




CONSTANT CURRENT SOURCE   circuit 4

The output will be limited to 100mA by using a red LED and 10R for Re.
The output will be limited to 500mA by using a red LED and 2R2 for Re.
BC328 - 800mA max
Use a BD140 in the first circuit and the output will be limited to 1A by using a red LED and 1R0 for R_e.
5watt LEDs (sometimes called "White Big Chip LEDs") have a characteristic voltage across them of 3.2v and draw 1.75amp.
1, 2 or 3 can be connected in series to the second circuit using a heatsinked BD140 transistor.

-

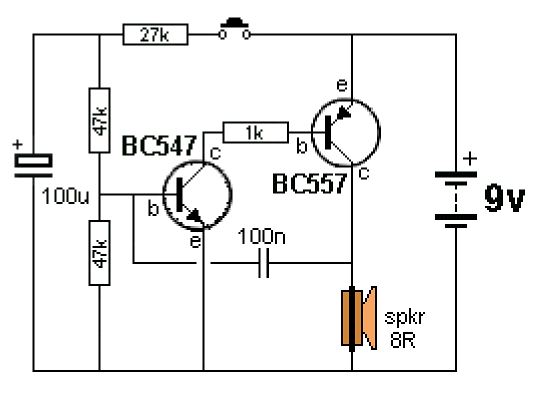


ON - OFF VIA MOMENTARY PUSH-BUTTONS

- see Also Push-ON Push-OFF (in 101-200 Circuits)

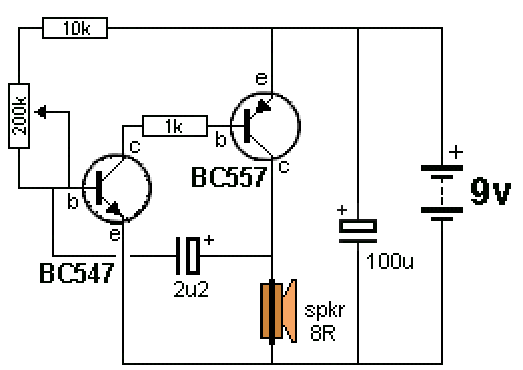
This circuit will supply current to the load R_L. The maximum current will depend on the second transistor. The circuit is turned on via the "ON" push button and this action puts a current through the load and thus a voltage develops across the load. This voltage is passed to the PNP transistor and it turns ON. The collector of the PNP keeps the power transistor ON.
To turn the circuit OFF, the "OFF" button is pressed momentarily. The 1k between base and emitter of the power transistor prevents the base floating or receiving any slight current from the PNP transistor that would keep the circuit latched ON.
The circuit was originally designed by a Professor of Engineering at Penn State University. It had 4 mistakes. So much for testing a circuit!!!! It has been corrected in the circuit on the left.

-



SIREN

This circuit produces a wailing or siren sound that gradually increases and decreases in frequency as the 100u charges and discharges when the push-button is pressed and released. In other words, the circuit is not automatic. You need to press the button and release it to produce the up/down sound.

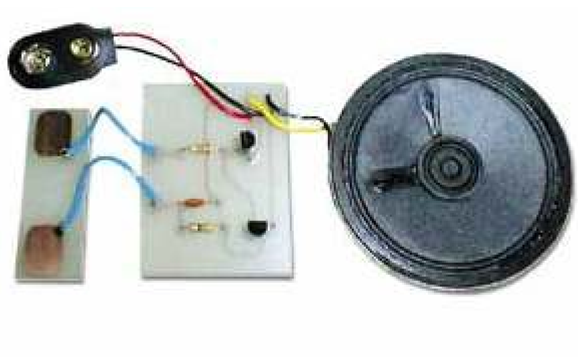


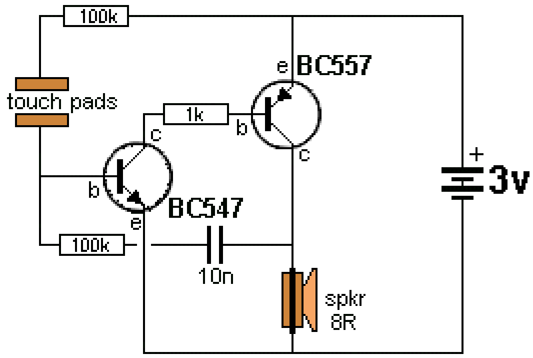
TICKING BOMB

This circuit produces a sound similar to a loud clicking clock. The frequency of the tick is adjusted by the 220k pot.

The circuit starts by charging the 2u2 and when 0.65v is on the base of the NPN transistor, it starts to turn on. This turns on the BC 557 and the voltage on the collector rises. This pushes the small charge on the 2u2 into the base of the BC547 to turn it on more.

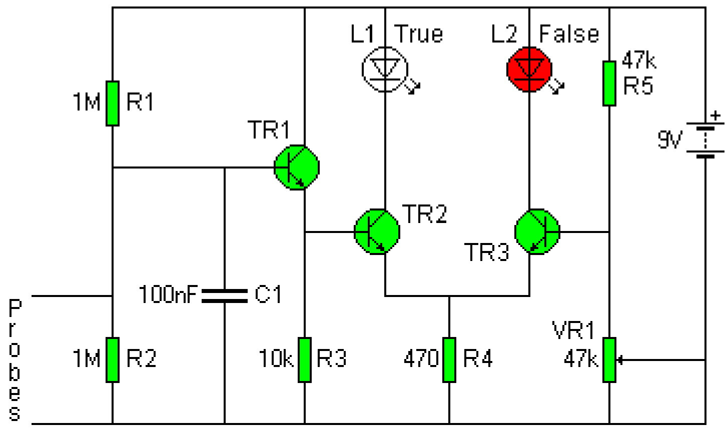
This continues when the negative end of the 2u2 is above 0.65v and now the electro starts to charge in the opposite direction until both transistors are fully turned on. The BC 547 receives less current into the base and it starts to turn off. Both transistors turn off very quickly and the cycle starts again.





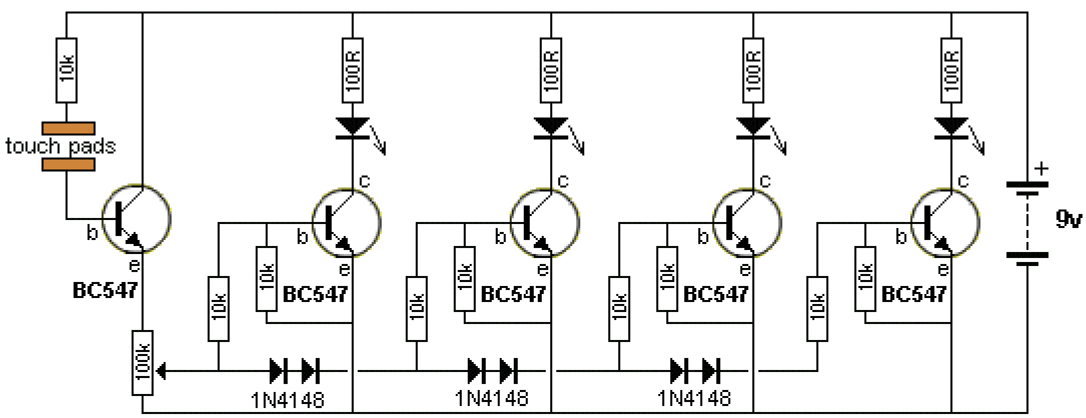
LIE DETECTOR-1

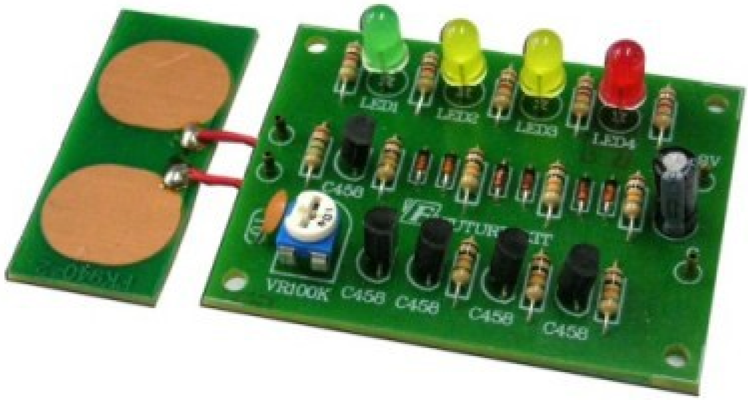
This circuit detects the resistance between your fingers to produce an oscillation. The detection-points will detect resistances as high as 300k and as the resistance decreases, the frequency increases.
Separate the two touch pads and attach them to the back of each hand. As the subject feels nervous, he will sweat and change the frequency of the circuit.
The photos show the circuit built on PC boards with separate touch pads.



LIE DETECTOR-2

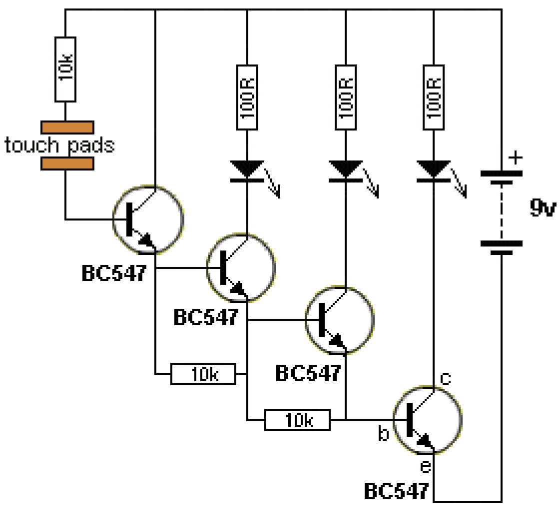
This circuit detects the resistance between your fingers to turn on the FALSE LED. The circuit sits with the TRUE LED illuminated. The 47k pot is adjusted to allow the LEDs to change state when touching the probes.





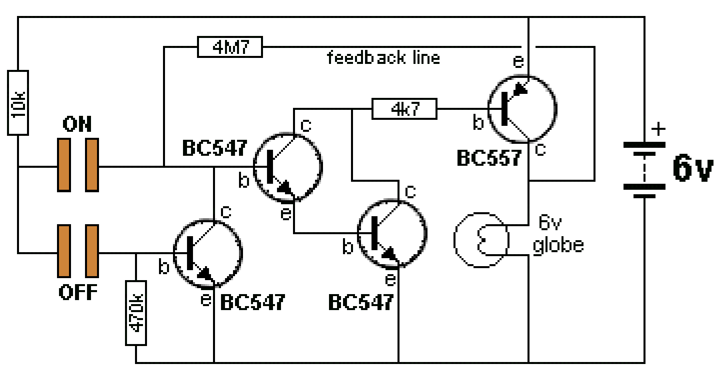
LIE DETECTOR-3

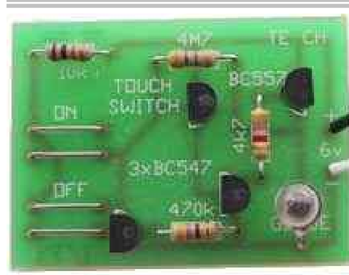
This circuit detects the resistance between your fingers to turn the 4 LEDs. As you press harder, more LEDs are illuminated.



LIE DETECTOR-4

This circuit detects the resistance between your fingers to turn the 3LEDs. As you press harder, more LEDs are illuminated. The circuit is simpler than **Lie Detector-3**.





TOUCH SWITCH - globe

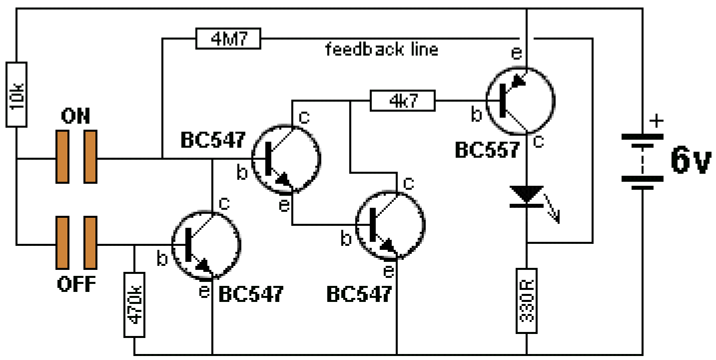
This circuit detects the skin resistance of a finger to deliver a very small current to the super-alpha pair of transistors to turn the circuit ON. The output of the "super transistor" turns on the BC 557 transistor. The voltage on the top of the globe is passed to the front of the circuit via the 4M7 to take the place of your finger and the circuit remains ON.

To turn the circuit OFF, a finger on the OFF pads will activate the first transistor and this will rob the "super transistor" of voltage and the circuit will turn OFF.

This project is available as a kit of parts from Talking Electronics for $6.00 plus $4.00

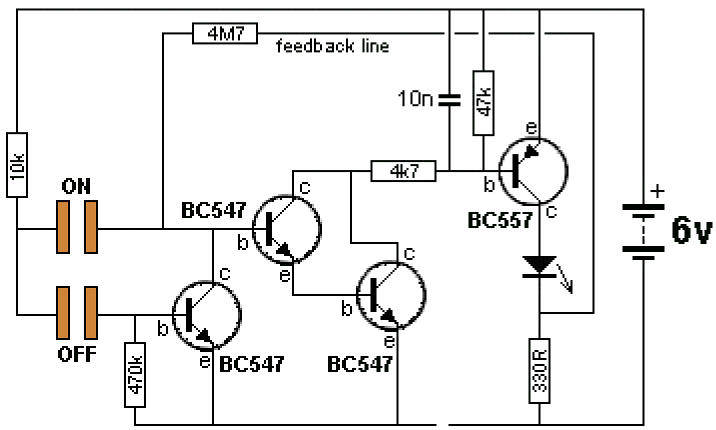
postage.

TOUCH SWITCH - LED

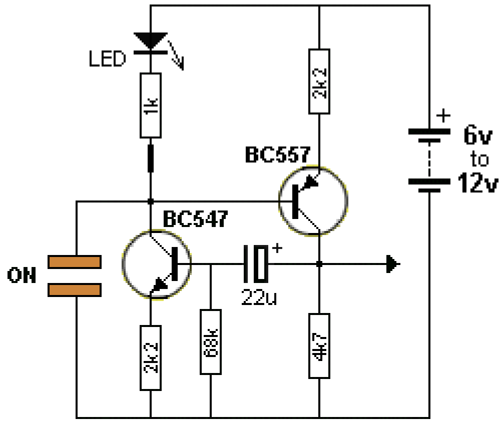


This circuit turns a LED on and off.

TOUCH SWITCH - LED - modification by Mike Grozak
To make the circuit come ON with the LED not illuminated, you need to put a "set" on the circuit.
A "set" is a particular condition that may be ON or OFF but the fact is the circuit ALWAYS starts in a particular way.

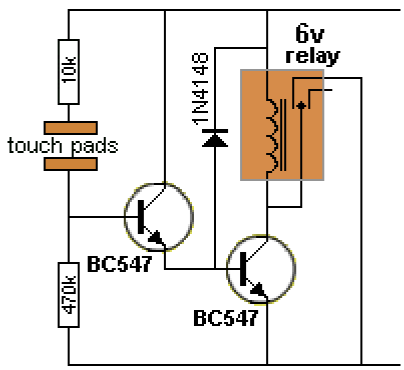


The 10n prevents a voltage appearing on the base of the BC557 transistor when the circuit is turned ON and this means the transistor is OFF. The feedback line will not have any voltage on it and thus the second and third transistor will not be turned ON. Thus the circuit will come ON with the LED not illuminated.



TOUCH SWITCH-2

This circuit detects the skin resistance of a finger to turn the circuit ON for about 1 second. The output can be taken to a counting circuit. The circuit consumes no current when in quiescent mode:



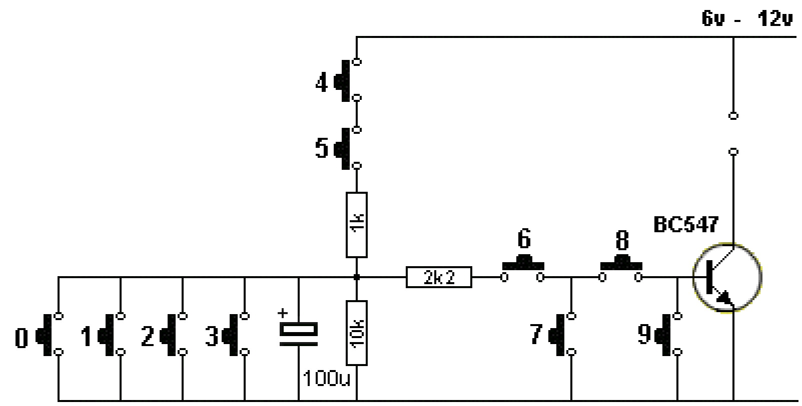
TOUCH SWITCH-3

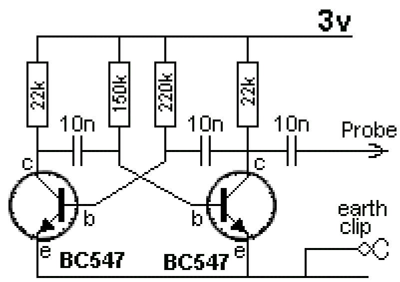
This circuit stays ON.

-

CODE PAD

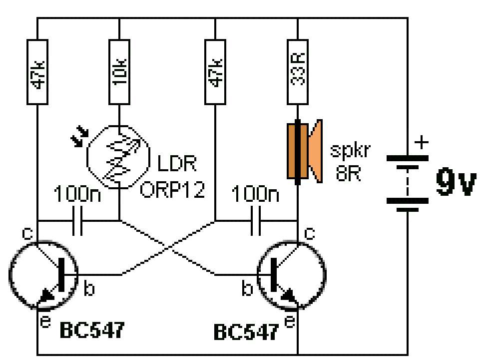
Here is a simple CODE PAD to add to your alarm. It consists of 10 buttons and they must be pressed in a certain order for the output to change. You can see from the circuit how the buttons are pressed and two buttons must be pressed at the same time, the two other buttons at the same time, to gain entry. The operation of this type of pad is very unusual as anyone pressing the buttons by incrementing numbers will not be able to produce the code.





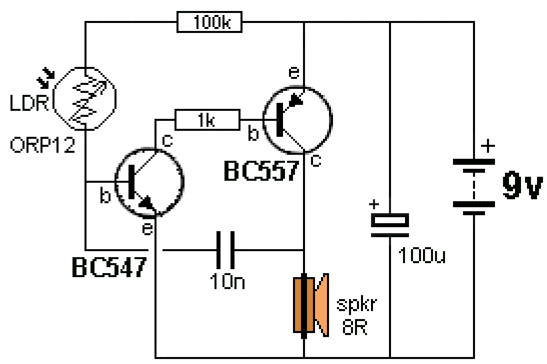
SIGNAL INJECTOR

This circuit is rich in harmonics and is ideal for testing amplifier circuits. To find a fault in an amplifier, connect the earth clip to the 0v rail and move through each stage, starting at the speaker. An increase in volume should be heard at each preceding stage. This Injector will also go through the IF stages of radios and FM sound sections in TV's.



LIGHT ALARM - 1

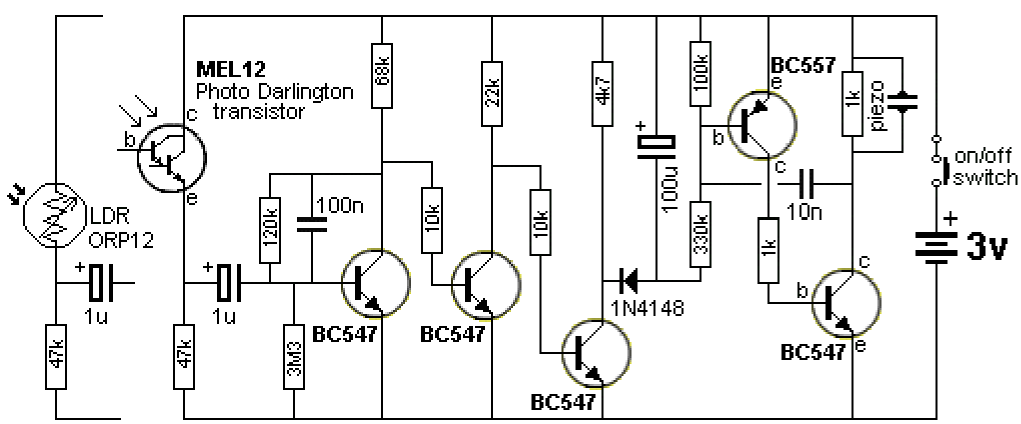
This circuit operates when the Light Dependent Resistor receives light.
When no light falls on the LDR, its resistance is high and the transistor driving the speaker is not turned on.
When light falls on the LDR its resistance decreases and the collector of the second transistor falls. This turns off the first transistor slightly via the second 100n and the first 100n puts an additional spike into the base of the second transistor. This continues until the second transistor is turned on as hard as it can go. The first 100n is now nearly charged and it cannot keep the second transistor turned on. The second transistor starts to turn off and both transistors swap conditions to produce the second half of the cycle.



LIGHT ALARM - 2

This circuit is similar to Light Alarm -1 but produces a louder output due to the speaker being connected directly to the circuit.

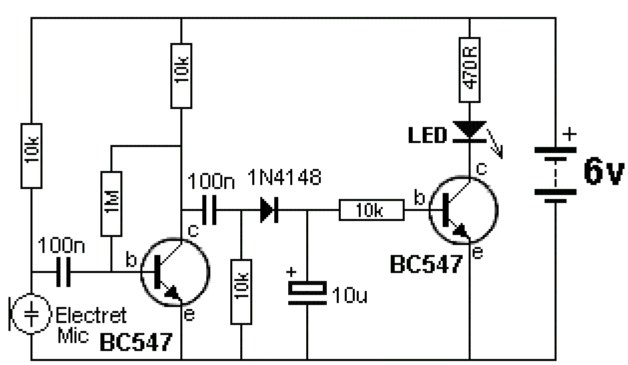
The circuit is basically a high-gain amplifier that is turned on initially by the LDR and then the 10n keeps the circuit turning on until it can turn on no more. The circuit then starts to turn off and eventually turns off completely. The current through the LDR starts the cycle again.



LIGHT ALARM - 3 (MOVEMENT DETECTOR)

This circuit is very sensitive and can be placed in a room to detect the movement of a person up to 2 metres from the unit.

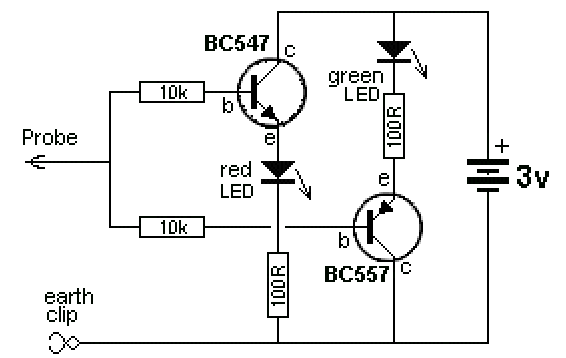
The circuit is basically a high-gain amplifier (made up of the first three transistors) that is turned on by the LDR or photo Darlington transistor. The third transistor charges the 100u via a diode and this delivers turn-on voltage for the oscillator. The LDR has equal sensitivity to the photo transistor in this circuit.



SOUND TRIGGERED LED

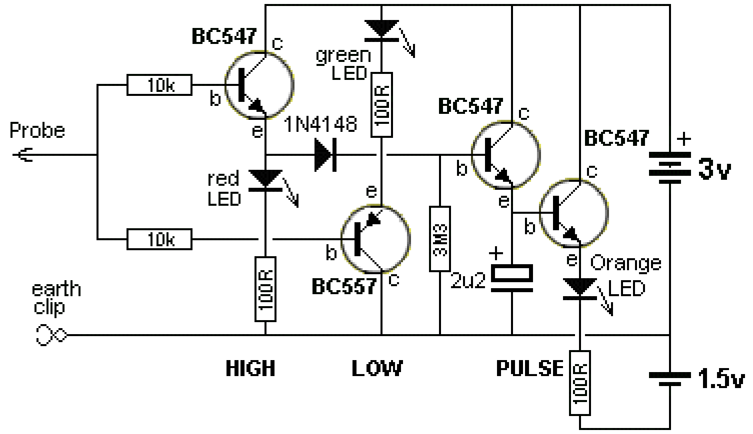
This circuit turns on a LED when the microphone detects a loud sound.

The "charge-pump" section consists of the 100n, 10k, signal diode and 10u electrolytic. A signal on the collector of the first transistor is passed to the 10u via the diode and this turns on the second transistor, to illuminate the LED.



SIMPLE LOGIC PROBE

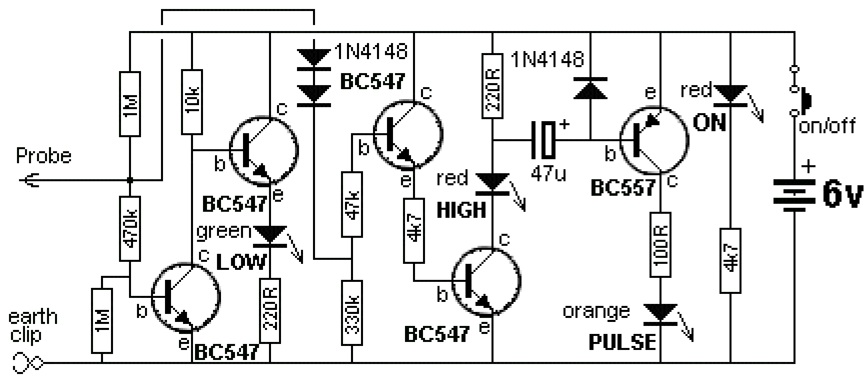
This circuit consumes no current when the probe is not touching any circuitry. The reason is the voltage across the green LED, the base-emitter junction of the BC557, plus the voltage across the red LED and base-emitter junction of the BC547 is approx: 2.1v + 0.6v + 1.7v + 0.6v = 5v and this is greater than the supply voltage.
When the circuit detects a LOW, the BC557 is turned on and the green LED illuminates. When a HIGH (above 2.3v) is detected, the red LED is illuminated.



SIMPLE LOGIC PROBE with PULSE

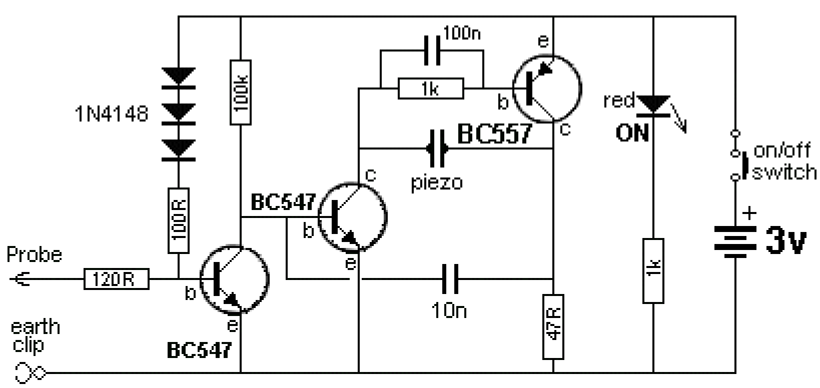
This circuit consumes no current when the probe is not touching any circuitry and the input has a surprisingly HIGH IMPEDANCE. Keep the probe away from stray signals (especially mains hum) as the orange LED will illuminate.
When the red LED illuminates, the HIGH is passed through the 1N4148 diode and the third transistor is an emitter-follower. It increases the current-capability of the pulse and charges a 2u2.
The 4th transistor increases the capacity of the 2u2 by about 100 times to make it a 220u electro to keep the orange LED illuminated for a few milliseconds after the pulse has ceased.
The voltage-drop across the diode and base-emitter junctions of the transistors reduces the voltage on the emitter of the 4th transistor to less than

	1v and an extra 1.5v is needed from the supply to illuminate the orange LED.



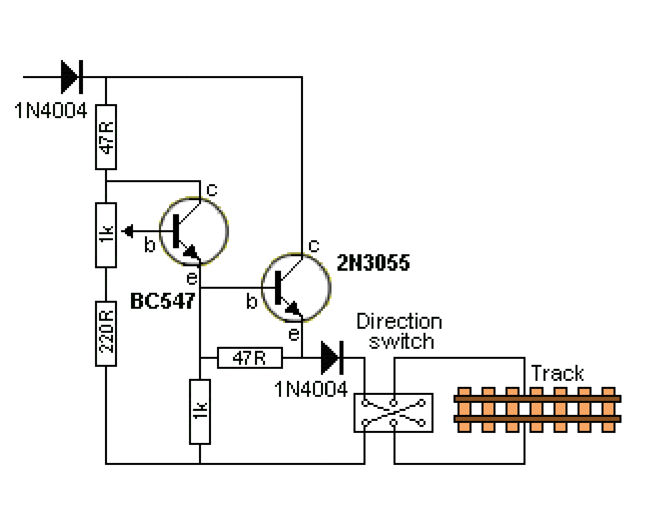
LOGIC PROBE with PULSE

This circuit has the advantage of providing a PULSE LED to show when a logic level is HIGH and pulsing at the same time. It can be built for less than $5.00 on a piece of matrix board or on a small strip of copper clad board if you are using surface mount components. The probe will detect a HIGH at 3v and thus the project can be used for 3v, 5v and CMOS circuits.



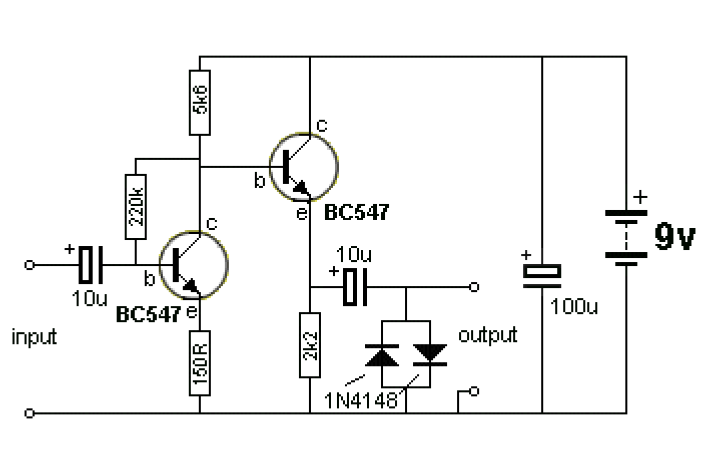
CONTINUITY TESTER

This circuit has the advantage of providing a beep when a short-circuit is detected but does not detect the small voltage drop across a diode. This is ideal when testing logic circuits as it is quick and you can listen for the beep while concentrating on the probe. Using a multimeter is much slower.



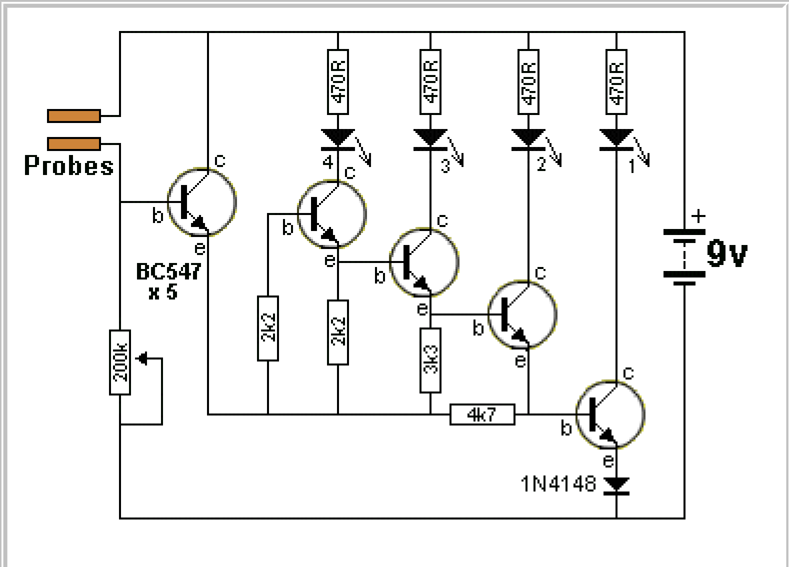
TRAIN THROTTLE

This circuit is for model train enthusiasts. By adding this circuit to your speed controller box, you will be able to simulate a train starting slowly from rest.
Remove the wire-wound rheostat and replace it with a 1k pot. This controls the base of the BC547 and the 2N3055 output is controlled by the BC547. The diodes protect the transistors from reverse polarity from the input and spikes from the rails.



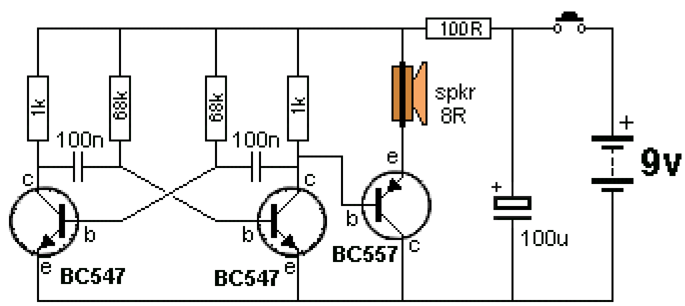
GUITAR FUZZ

The output of a guitar is connected to the input of the Fuzz circuit. The output of this circuit is connected to the input of your amplifier. With the guitar at full volume, this circuit is overdriven and distorts. The distorted signal is then clipped by the diodes and your power amp amplifies the Fuzz effect.



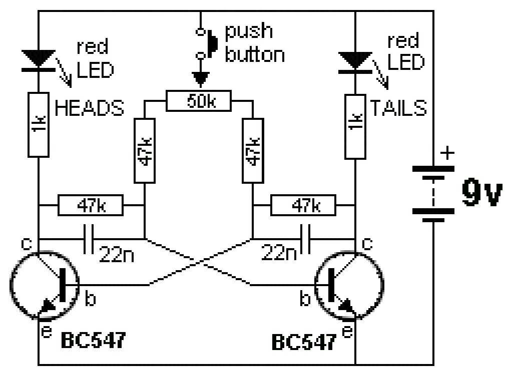
STRENGTH TESTER

This is a simple "staircase" circuit in which the LEDs come on as the resistance between the probes decreases.
When the voltage on the base of the first transistor sees 0.6v + 0.6v + 0.6v = 1.8v, LED1 comes on. LEDs 1&2 will come on when the voltage rises a further 0.6v. The amount of pressure needed on the probes to produce a result, depends on the setting of the 200k pot.



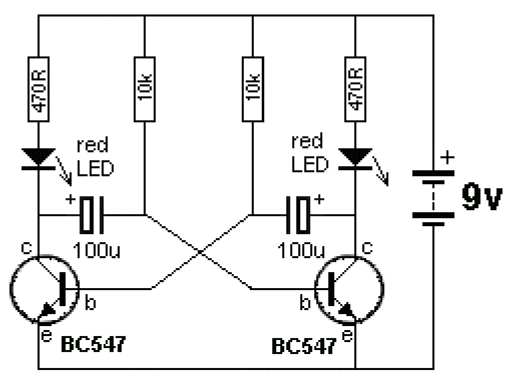
FOG HORN

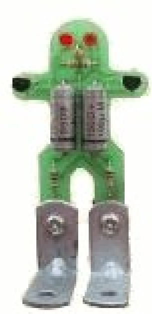
When the push-button is pressed, the 100u will take time to charge and this will provide the rising pitch and volume. When the push-button is released, the level and pitch will die away. This is the characteristic sound of a ship's fog horn.



HEADS OR TAILS

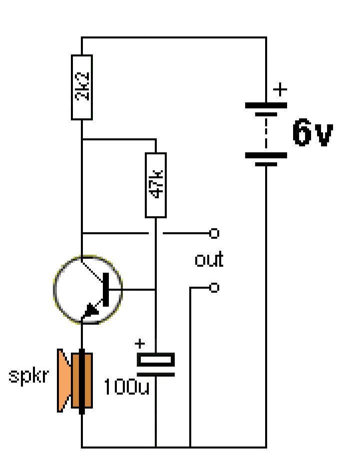
When the push-button is pressed, the circuit will oscillate at a high rate and both LEDs will illuminate. When the push button is released, one of the LEDs will remain illuminated. The 50k is designed to equalise the slightly different values on each half of the circuit and prevent a "bias."





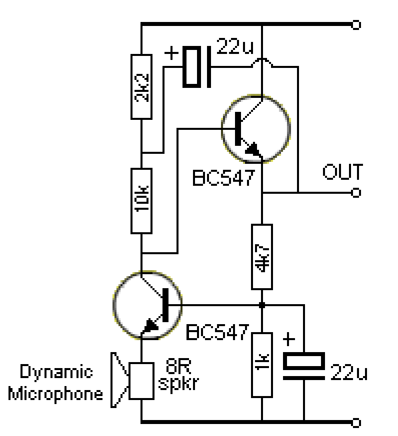
ROBOT MAN

This multivibrator circuit will flash the Robot Man's eyes as shown in the photo. The kit of components is available from Talking Electronics for $8.50 plus postage. Send an email to find out the cost of postage: talking@tpg.com.au



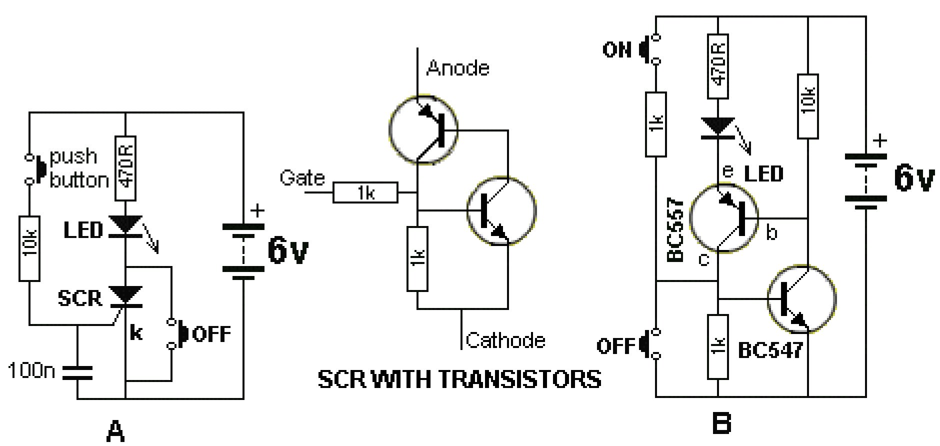
DYNAMIC MICROPHONE AMPLIFIER

This circuit takes the place of an electret microphone. It turns an ordinary mini speaker into a very sensitive microphone.
Any NPN transistors such as BC 547 can be used. The circuit will work from 3v to 9v. It is a common-base amplifier and accepts the low impedance of the speaker to produce a gain of more than 100.



DYNAMIC MICROPHONE AMPLIFIER-2

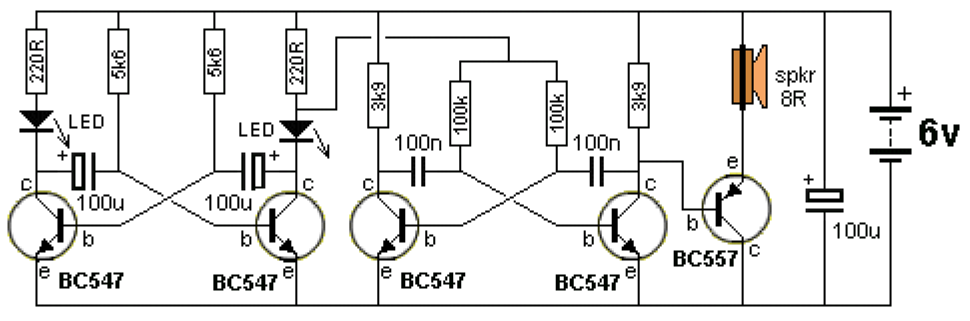
This circuit is a BOOTSTRAP design. It turns an ordinary mini speaker into a very sensitive microphone.
Any NPN transistors such as BC 547 can be used. The circuit will work from 6v to 12v. It has been taken from our **Stereo VU Meter** project.



SCR WITH TRANSISTORS

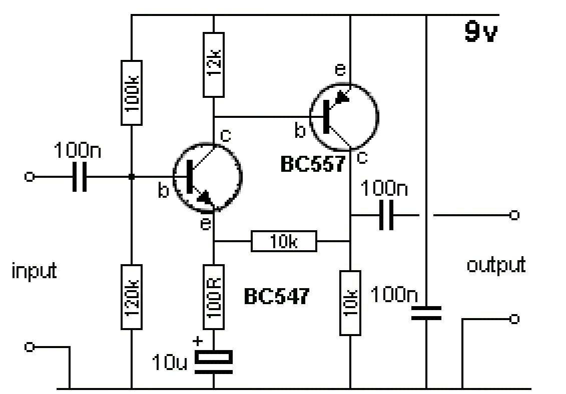
The SCR in circuit A produces a 'LATCH.' When the button is pressed, the LED remains illuminated.
The SCR can be replaced with two transistors as shown in circuit B.
To turn off circuit A, the current through the SCR is reduced to zero by the action of the OFF button. In circuit B the OFF button removes the voltage on the base of

the BC547. The OFF button could be placed across the two transistors and the circuit will turn off.



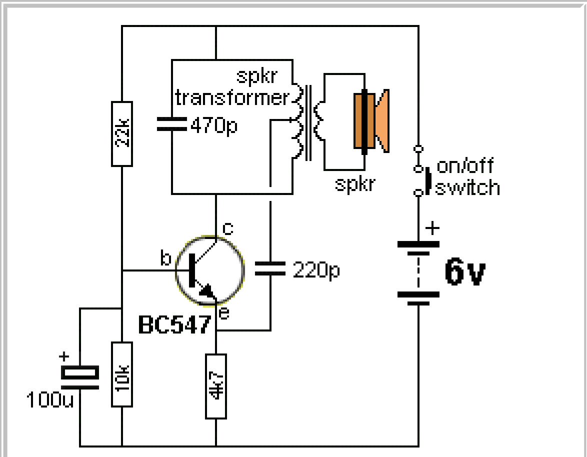
HEE HAW SIREN

The circuit consists of two multivibrators. The first multi-vibrator operates at a low frequency and this provides the speed of the change from Hee to Haw. It modifies the voltage to the tone multivibrator, by firstly allowing full voltage to appear at the bottom of the 220R and then a slightly lower voltage when the LED is illuminated.



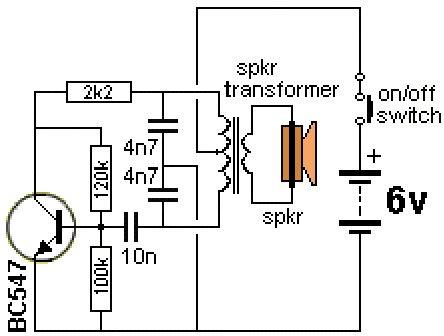
MICROPHONE PRE-AMPLIFIER

This circuit consists of two directly coupled transistors operating as common-emitter amplifiers.
The ratio of the 10k resistor to the 100R sets the gain of the circuit at 100.



HARTLEY OSCILLATOR

The Hartley Oscillator is characterised by an LC circuit in its collector. The base of the transistor is held steady and a small amount of signal is taken from a tapping on the inductor and fed to the emitter to keep the transistor in oscillation.
The transformer can be any speaker transformer with centre-tapped primary.
The frequency is adjusted by changing the 470p.



COLPITTS OSCILLATOR

The Colpitts Oscillator is characterised by tapping the mid-point of the capacitive side of the oscillator section. The inductor can be the primary side of a speaker transformer. The feedback comes via the inductor.

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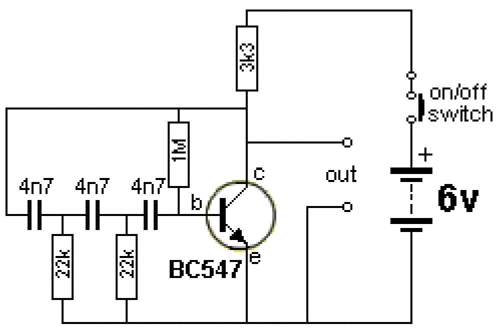

PHASESHIFT OSCILLATOR

The Phaseshift Oscillator is characterised by 3 high-pass filters, creating a 180° phase shift. The output is a sinewave. Take care not to load the output - this will prevent reliable start-up and may stop the circuit from oscillating. Reduced the 3k3 load resistor if the load prevents the circuit oscillating. See Phase Shift Oscillator in second section of 200 Transistor Circuits for a better design.

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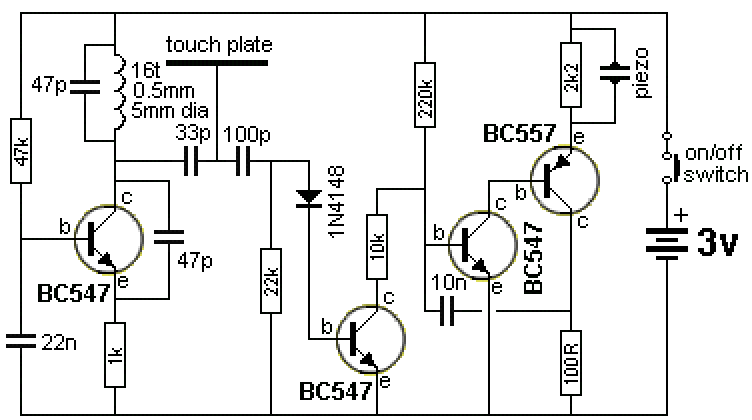


DOOR-KNOB ALARM

This circuit can be used to detect when someone touches the handle of a door. A loop of bare wire is connected to the point "touch plate" and the project is hung on the door-knob. Anyone touching the metal door-knob will kill the pulses going to the second transistor and it will turn off. This will activate the "high-gain" amplifier/oscillator.

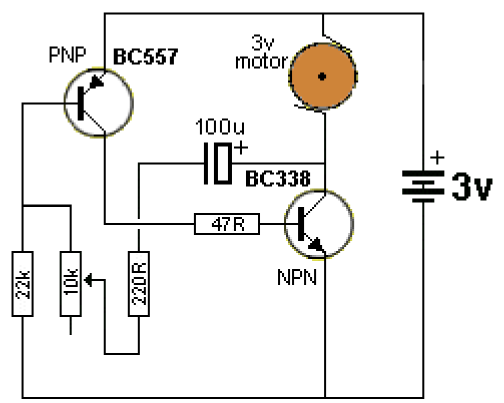
The circuit will also work as a "Touch Plate" as it does not rely on mains hum, as many other circuits do.

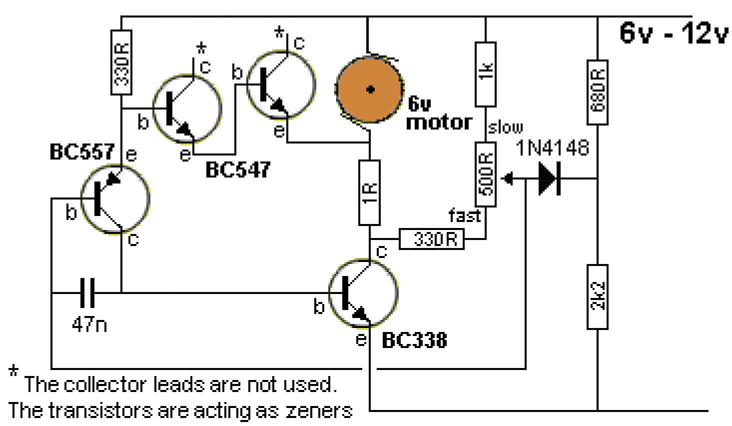
-

SIMPLE MOTOR SPEED CONTROL

This circuit is better than reducing the RPM of a motor via a resistor. Firstly it is more efficient. And

secondly it gives the motor a set of pulses and this allows it to start at low RPM. It's a simple Pulse-Width circuit or Pulse-Circuit.





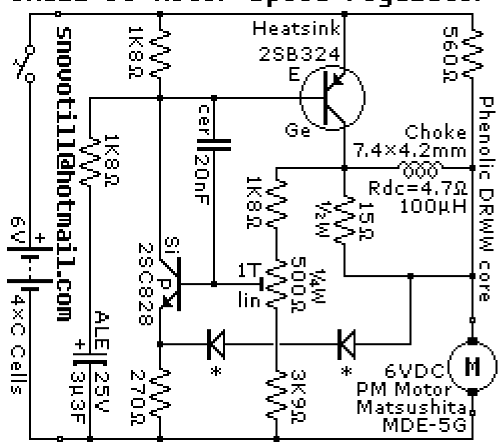
MOTOR SPEED CONTROLLER

Most simple motor speed controllers simply reduce the voltage to a motor by introducing a series resistance. This reduces the motor's torque and if the motor is stopped, it will not start again.

This circuit detects the pulses of noise produced by the motor to turn the circuit off slightly. If the motor becomes loaded, the amplitude of the pulses decreases and the circuit turns on more to deliver a higher current.

MOTOR SPEED CONTROL - Circuit 3

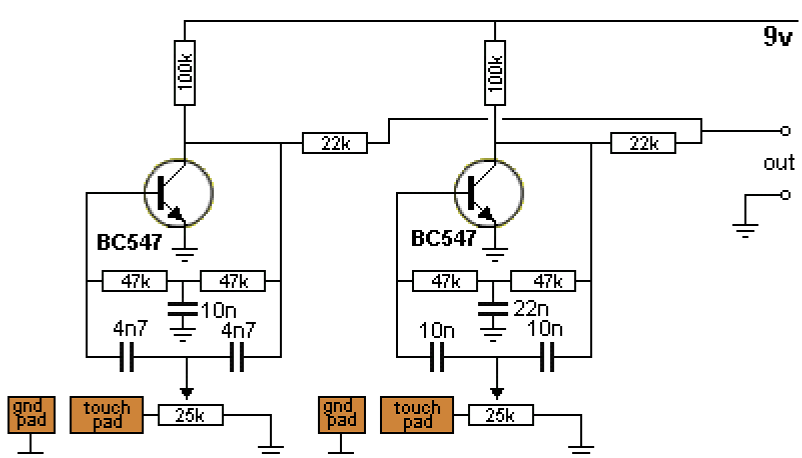
Small DC motor speed regulator



http://members.shaw.ca/novotill

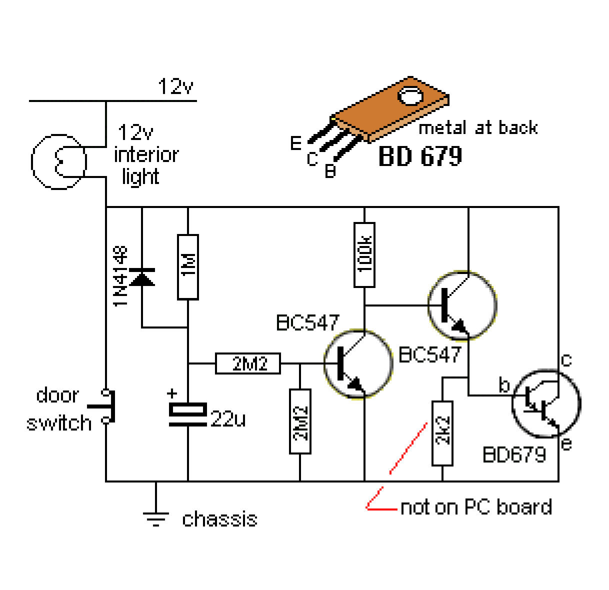
*Unmarked diodes are silicon so use 1N4148.
Top transistor is germanium running at Vbe of 200mV but silicon works perfectly fine as well.
Resistors are 1/4W CF 5% except as noted.
It's ok to use 4.7Ω resistor in place of choke.
Motor power draw under different loadings is:

- 32mA @ 2.4V under zero load freerunning.
- 80mA @ 2.8V under normal regulated load.
- 200mA @ 4V under normal maximum load.
- 300mA @ 4.5V is end of speed regulation.
- 460mA @ 3.9V shaft frozen motor stalled.



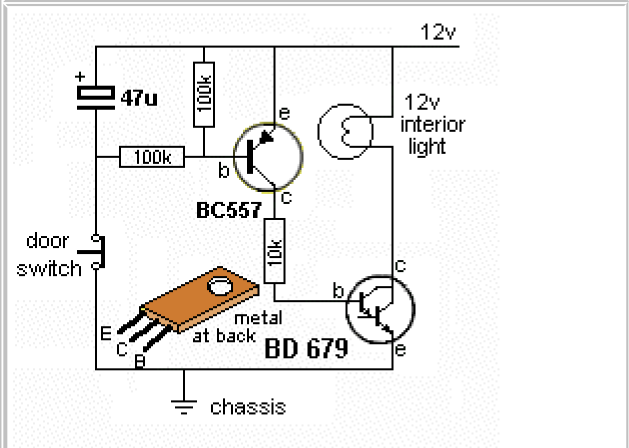
ELECTRONIC DRUMS

The circuit consists of two "twin-T" oscillators set to a point below oscillation. Touching a Touch Pad will set the circuit into oscillation. Different effects are produced by touching the pads in different ways and a whole range of effects are available.
The two 25k pots are adjusted to a point just before oscillation.
A "drum roll" can be produced by shifting a finger rapidly across adjacent ground and drum pads.



LIGHT EXTENDER

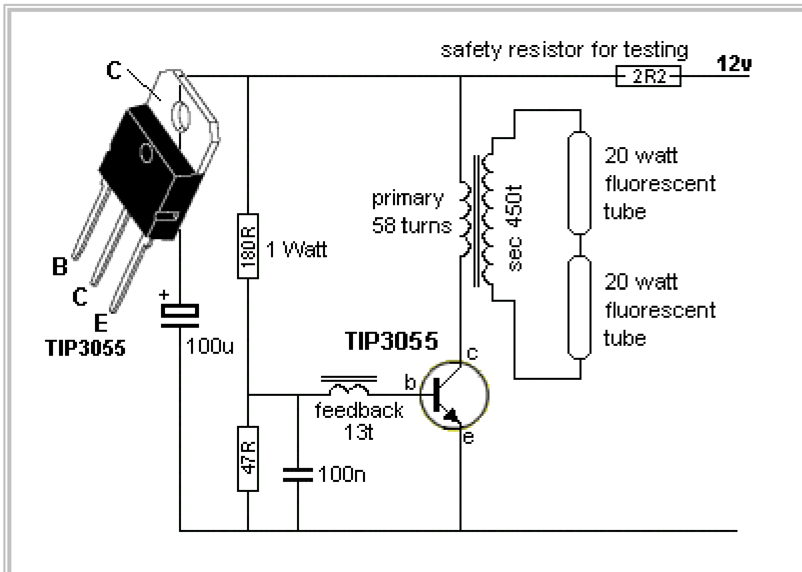
This circuit is a **Courtesy Light Extender** for cars. It extends the "ON" time when a door is closed in a car, so the passenger can see where he/she is sitting.
When the door switch is opened, the light normally goes off immediately, but the circuit takes over and allows current to flow because the 22u is not charged and the first BC 547 transistor is not turned ON. This turns on the second BC547 via the 100k and the BD679 is also turned on to illuminate the interior light.
The 22u gradually charges via the 1M and the first BC547 turns on, robbing the second BC547 of "turn-on" voltage and it starts to turn off the BD679.
The 1N4148 discharges the 22u when the door is opened. A 2k2 may needed to be added to completely turn off the globe.



LIGHT EXTENDER MkII

This circuit is a simpler **Courtesy Light Extender** for cars. It extends the "ON" time when a door is closed in a car. Both circuits perform exactly the same. This circuit is slightly simpler.
It uses only a single BC557 and BD679 transistor.

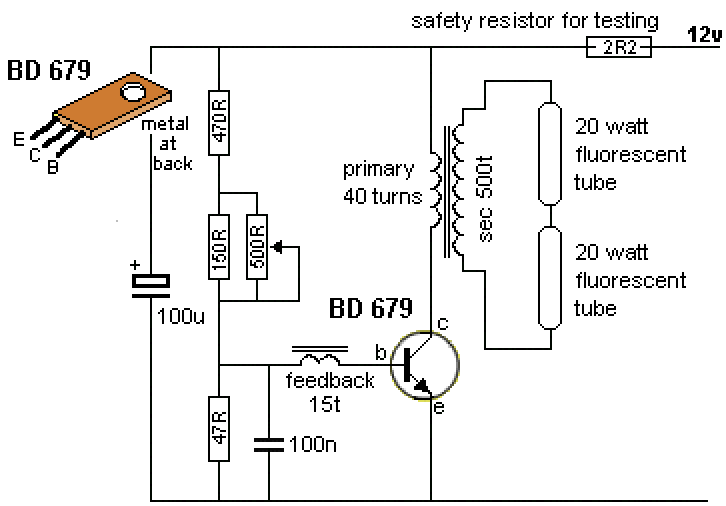
A Kit for this project is available from Talking Electronics for $5.20 plus postage. Click **Here** .



20 WATT FLUORO INVERTER

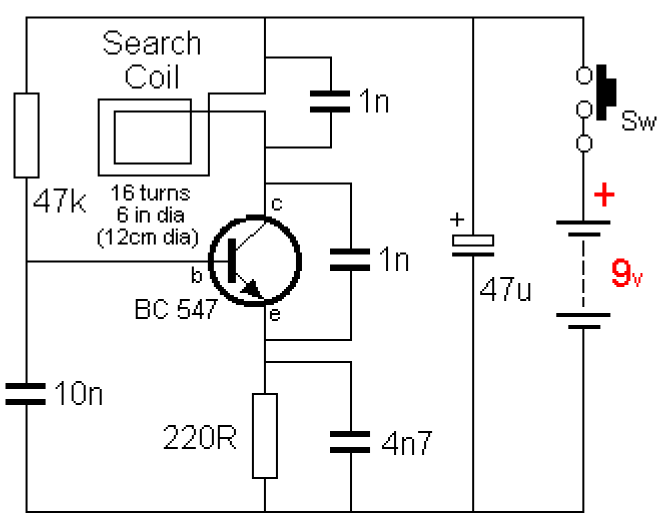
This circuit will drive a 40 watt fluoro or two 20-watt tubes in series.
The transformer is wound on a ferrite rod 10mm dia and 8cm long. The wire diameters are not critical but our prototype used 0.61mm wire for the primary and 0.28mm wire for the secondary and feedback winding.
Do not remove the tube when the circuit is operating as the spikes produced by the transformer will damage the transistor.
The circuit will take approx 1.5amp on 12v, making it more efficient than running the tubes from the mains. A

normal fluoro takes 20 watts for the tube and about 15 watts for the ballast.
A Kit for this project is available from Talking Electronics called Fluorescent Lamp Inverter for $12.50 plus postage. Click **Here**



6 to 12 WATT FLUORO INVERTER

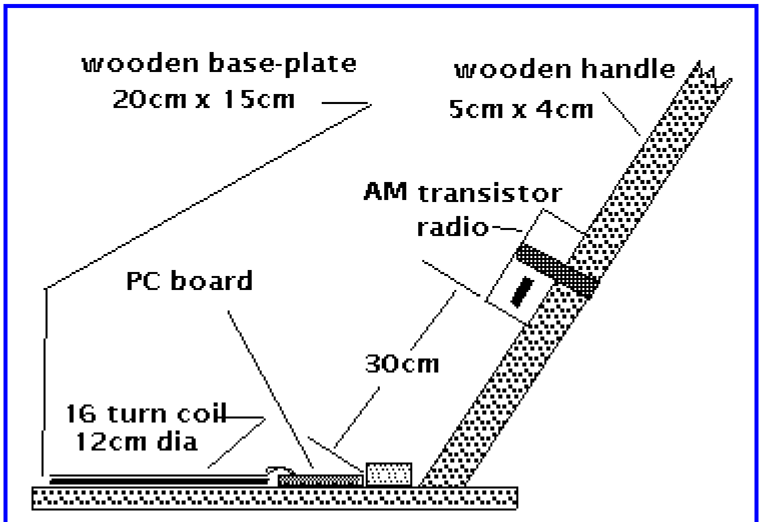
This circuit will drive a 40 watt fluoro or two 20-watt tubes in series but with less brightness than the circuit above and it will take less current.
2 x 20 watt tubes = 900mA to 1.2A and 1 x 20 watt tube 450mA to 900mA depending on pot setting.
The transformer is wound on a ferrite rod 10mm dia and 8cm long. The wire diameter is fairly critical and our prototype used 0.28mm wire for all the windings.
Do not remove the tube when the circuit is operating as the spikes produced by the transformer will damage the transistor. The pot will adjust the brightness and vary the current consumption. Adjust the pot and select the base-bias resistor to get the same current as our prototype. Heat-sink must be greater than 40sq cm. Use heat-sink compound.



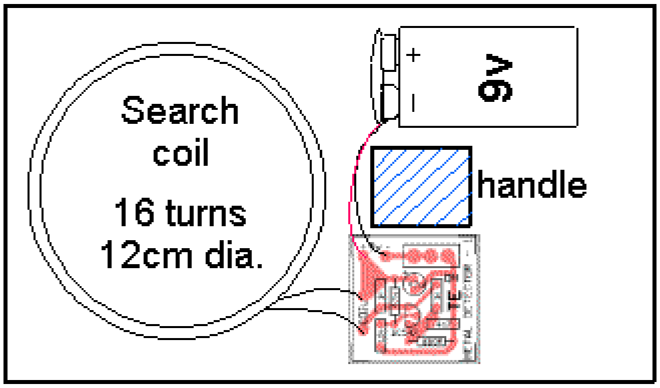
GOLD DETECTOR

see also:
BFO METAL DETECTOR in "100 IC circuits"
SIMPLE BFO METAL LOCATOR in "100 IC circuits"
METAL DETECTORS - article

This very simple circuit will detect gold or metal or coins at a distance of approx 20cm - depending on the size of the object.
The circuit oscillates at approx 140kHz and a harmonic of this frequency is detected by an AM



THE LAYOUT OF THE DETECTOR



The Layout of Metal Detector -1

radio.
Simply tune the radio until a squeal is detected.
When the search coil is placed near a metal object, the frequency of the circuit will change and this will be heard from the speaker.
The layout of the circuit is shown and the placement of the radio.

The TRUTH about Metal (GOLD) Detectors.

A Gold Detector's club in the US created a challenge with 12 members with skills ranging from 12 months detection to over 25 years. They used 5 different detectors to find 30 different items, hidden in sand and under pieces of cardboard.
The results were these: All detectors performed almost equally but the interpretation of the beeps, sounds and readings on the detector were quite often mis-read and the winner was a member with 1 year experience.
The moral of the story is to dig for anything that is detected as it may not be a "ring-pull."

With these findings you can clearly use a very simple, cheap, detector and get results equal to the most expensive equipment.
The only thing you have to remember is this: You need the right frequency for the type of soil to cancel out the effects of minerals etc.
That's why there is a range of frequencies from 6kHz to 150Hz.
All the other modes of producing and injecting the pulse add only a very small improvement to the detection process.
The energy put into the injecting pulse also has an influence of the depth of detection.

Buying Metal Detector kit:

Even though this circuit is the simplest you can get, it performs just like the $50.00 metal detectors because you use an ordinary AM radio to produce the tone. It will detect a small coin at 10cm.

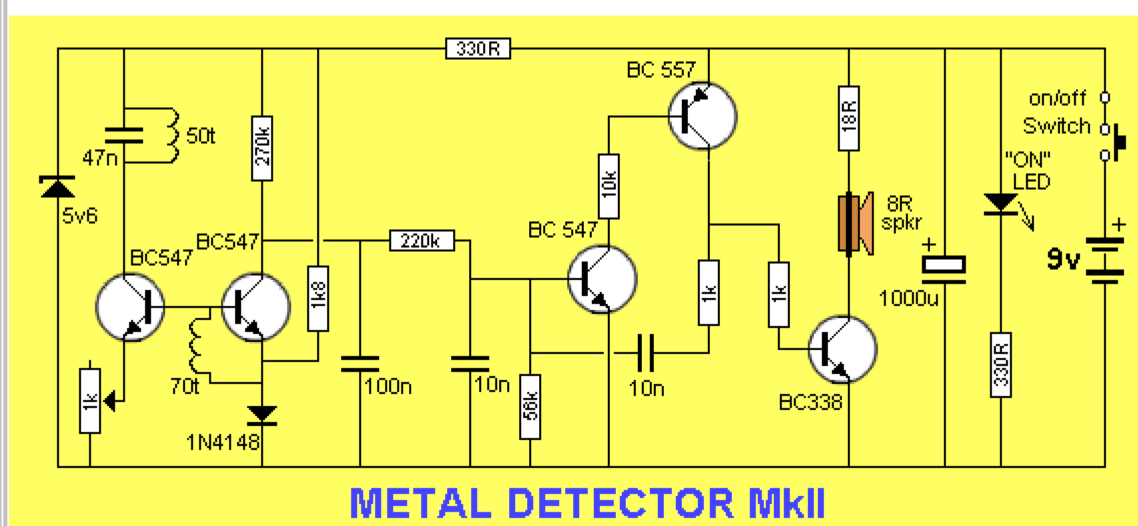
Metal Detector-1 kit: $14.00 FREE Shipping

Log in to your PayPal account and send a payment to: talking@tpg.com.au for $14.00 AUD

METAL DETECTOR MkII - see the full project: [Metal Detector MkII](#)

[Metal Detector kit MkII](#) $15.00 plus postage

This is a self-contained metal detector with about the same performance as Metal Detector-1 above.
All Metal detectors having the principle of detecting a metal object with a coil of about 12cm dia and operating at 100kHz, will have the same performance, no matter how complex the circuit.
They all rely on detecting the change in frequency as small as 1Hz or a voltage-change across a coil as small as 1uV.
The secret is to produce the largest waveform while loading the coil as lightly as possible. This allows the coil to detect metal at the furthest distance. See more details on [Metal Detector MkII](#)

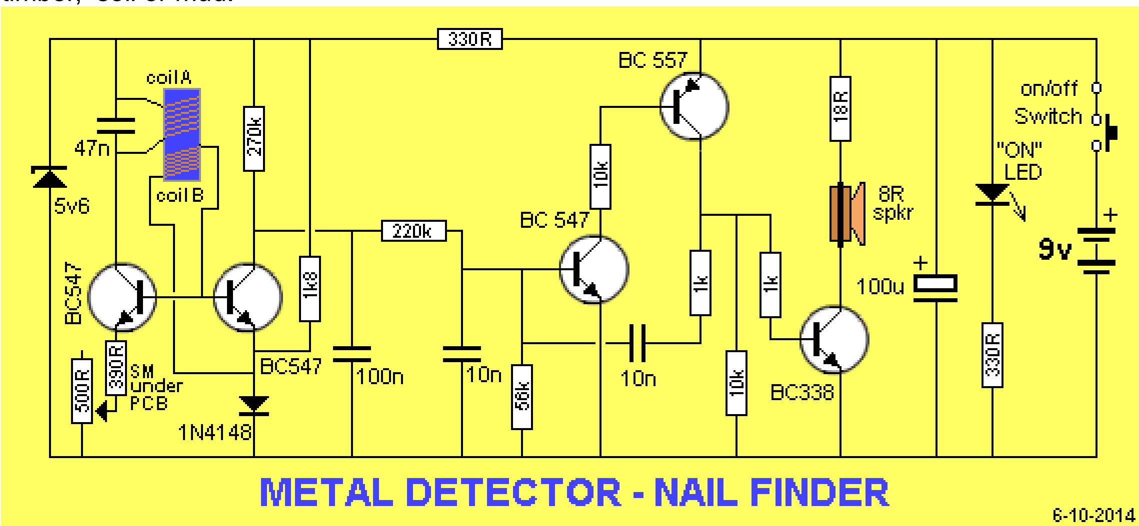


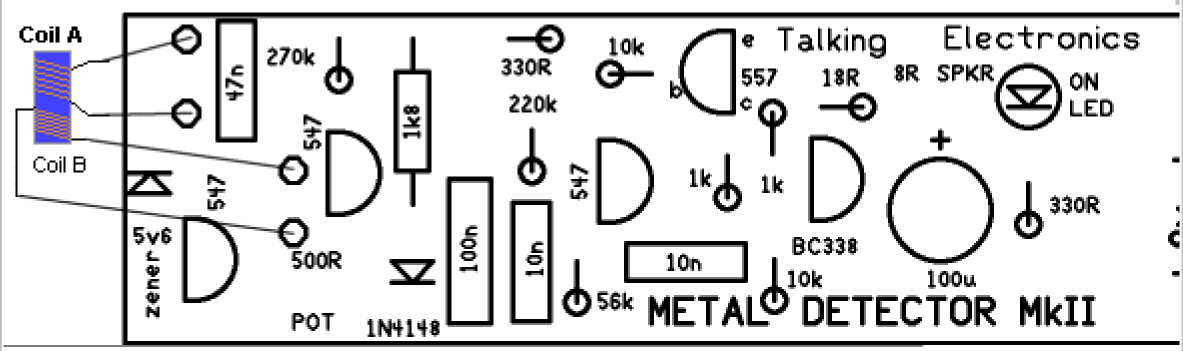
Nail Finder - see the full project: Metal Detector MkII

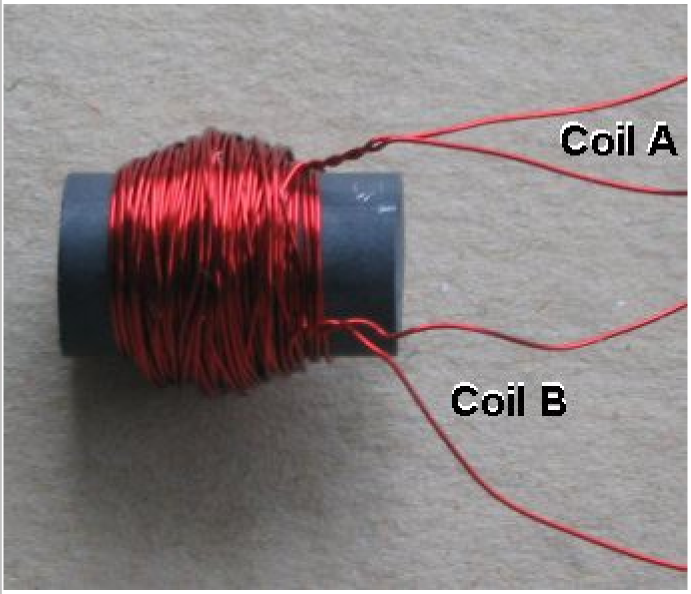
Kits for Metal Detector kit - Nail Finder $17.00 plus postage

This project is an extension of Metal Detector MkII, with a small detecting head to find tiny components such as nails and lost components.

This is an essential tool for servicemen and anyone trying to find a metal object hidden or buried in timber, soil or mud.







The Nail Finder head

The Nail Finder project is HERE

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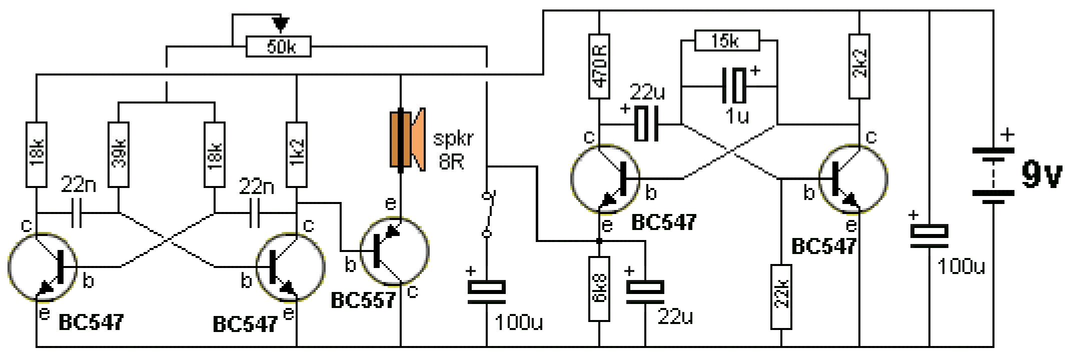

PHASER GUN

This is a very effective circuit. The sound is amazing. You have to build it to appreciate the range of effects it produces. The 50k pot provides the frequency of the sound while the switch provides fast or slow speed.

Hear the sounds: (built by a reader)

http://www.youtube.com/watch?v=JN_fBZxRpoU&feature=BFa&list=UU2oJeVi1pM3nQy_8X6fFHAA

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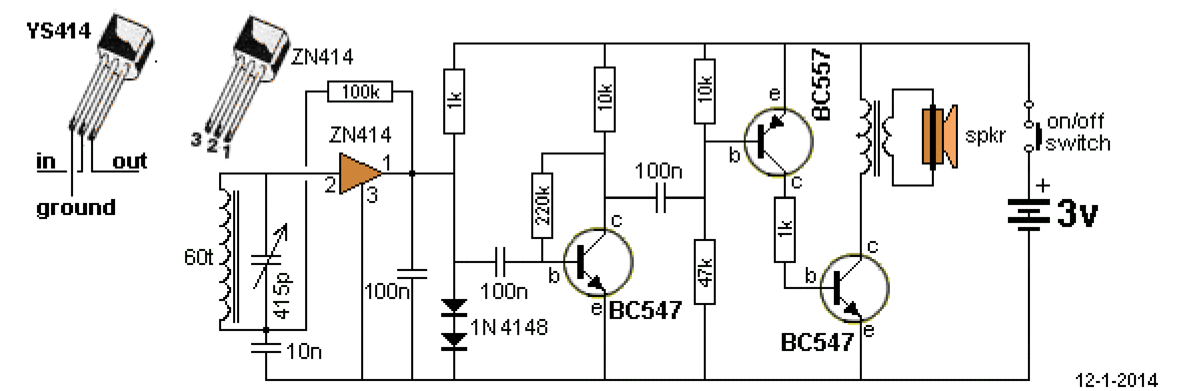
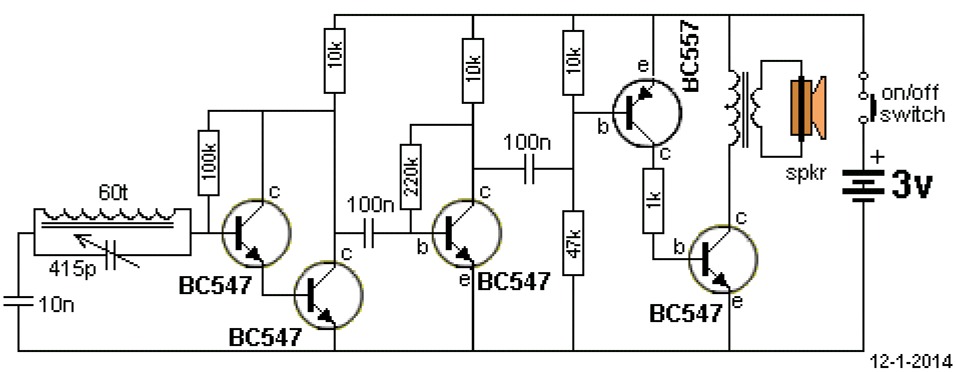


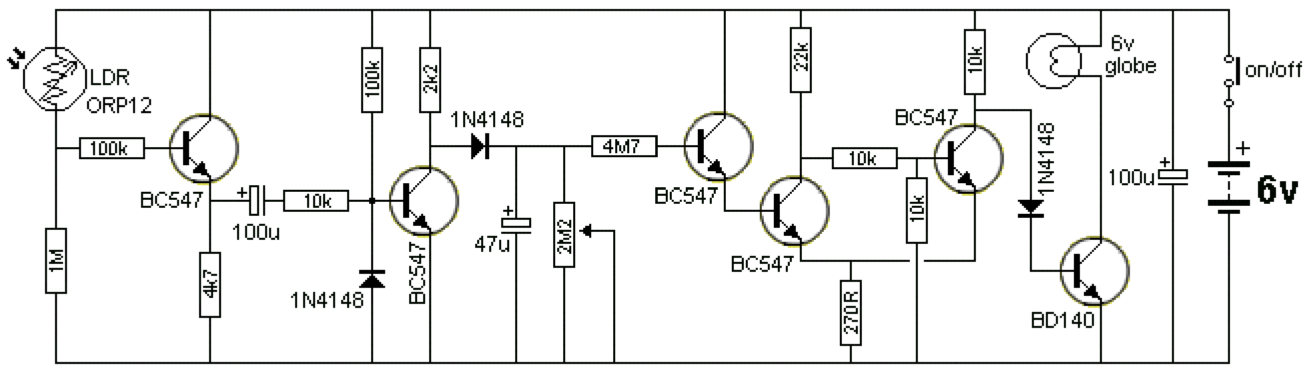
IC RADIO

This circuit contains an IC but it looks like a 3-leaded transistor and that's why we have included it here.
The IC is called a "Radio in a Chip" and it contains 10 transistors to produce a TRF (tuned Radio Frequency) front end for our project.
The 3-transistor amplifier is taken from our SUPER EAR project with the electret microphone removed.
The two 1N 4148 diodes produce a constant voltage of 1.3v for the chip as it is designed for a maximum of 1.5v.
The "antenna coil" is 60t of 0.25mm wire wound on a 10mm ferrite rod. The tuning capacitor can be any value up to 450p.
Note: The YS414 IC is identical to ZN414. See above.



5-TRANSISTOR RADIO

If you are not able to get the ZN414 IC, this circuit uses two transistors to take the place of the chip.



AUTOMATIC LIGHT

This circuit automatically turns on a light when illumination is removed from the LDR. It remains ON for the delay period set by the 2M2 pot.

The important feature of this circuit is the building blocks it contains - a delay circuit and Schmitt Trigger. These can be used when designing other circuits.

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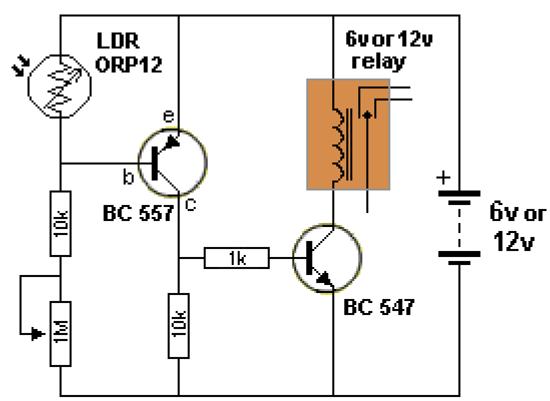
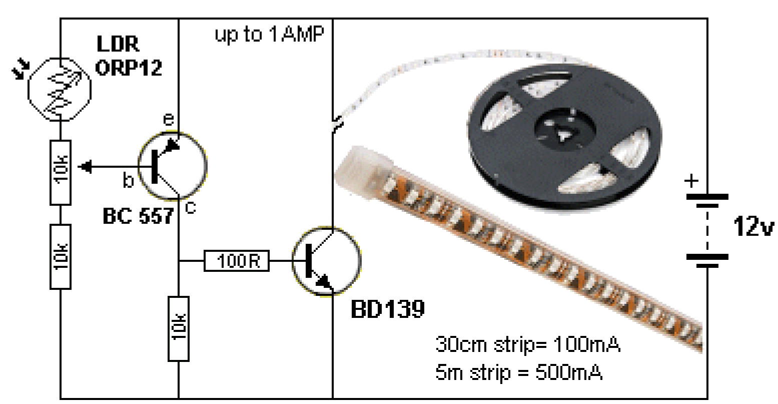


NIGHT LIGHT

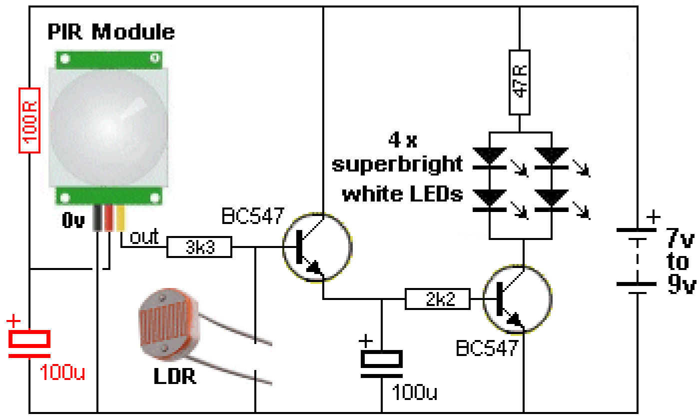
This circuit activates a relay when illumination falls below a preset level on the Light Dependent Resistor (Photo Cell).



This circuit will drive 30cm strips to 5m strips. Two 5m strips have been tested with this circuit.

PIR LED LIGHT

PIR detectors make a wonderful detector to turn on LEDs to illuminate a passage, doorway or path.
It has an LDR that only allows the circuit to turn ON at night.

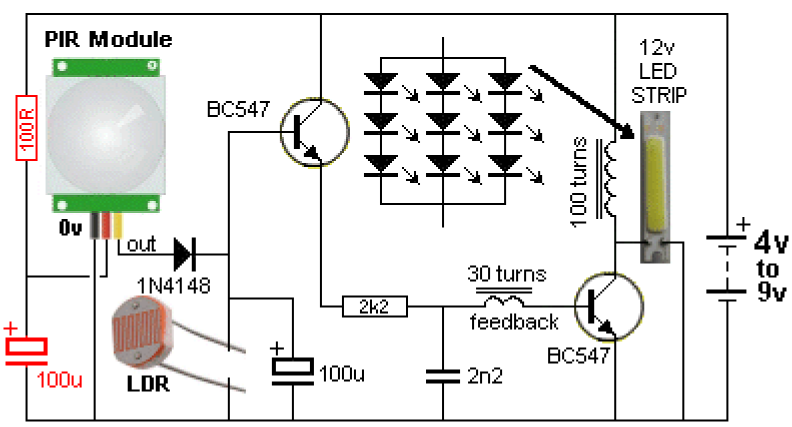


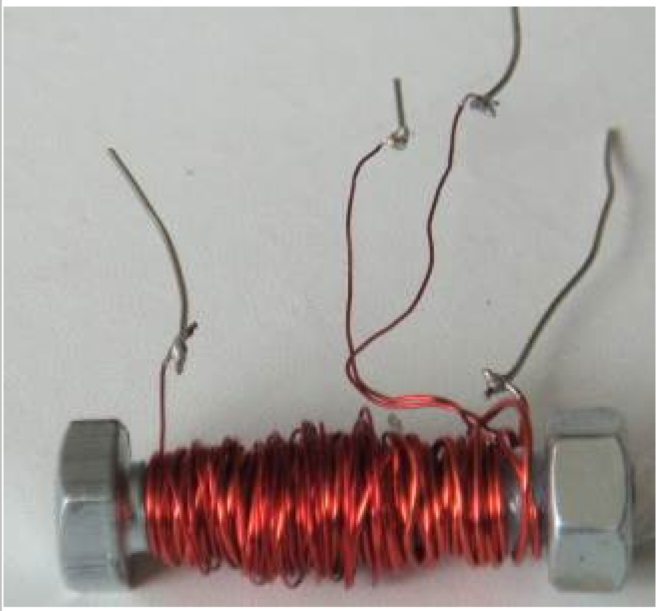
PIR LED LIGHT

This circuit can use old cells as it requires less than 20mA to illuminate the 4 LEDs and less than 0.4mA when sitting around.
There are a number of different PIR detectors and most of them take 1 minute to settle before detecting IR and turn ON for a short period of time. The 100u increases the turn-ON time to about 4 seconds and some detectors keep outputting a signal while you are in front of the lens.
The first transistor increases the current from the PIR module so the 100u can be charged via the 1k and the second transistor acts as a buffer to deliver current to turn on the LEDs.
The 100R and red 100u prevent the PIR re-triggering.
This is a great project for "using up" old batteries.
A kit for this project is available from Talking Electronics for $6.00 plus $4.50 postage.
It is built on a small piece of Matrix Board and includes 4 x super-bright LEDs. Email Colin Mitchell for details.

PIR LED LIGHT using LED STRIP

This circuit uses a home-made transformer, wound on a nut and bolt, and a 12v LED Strip or LED Panel.





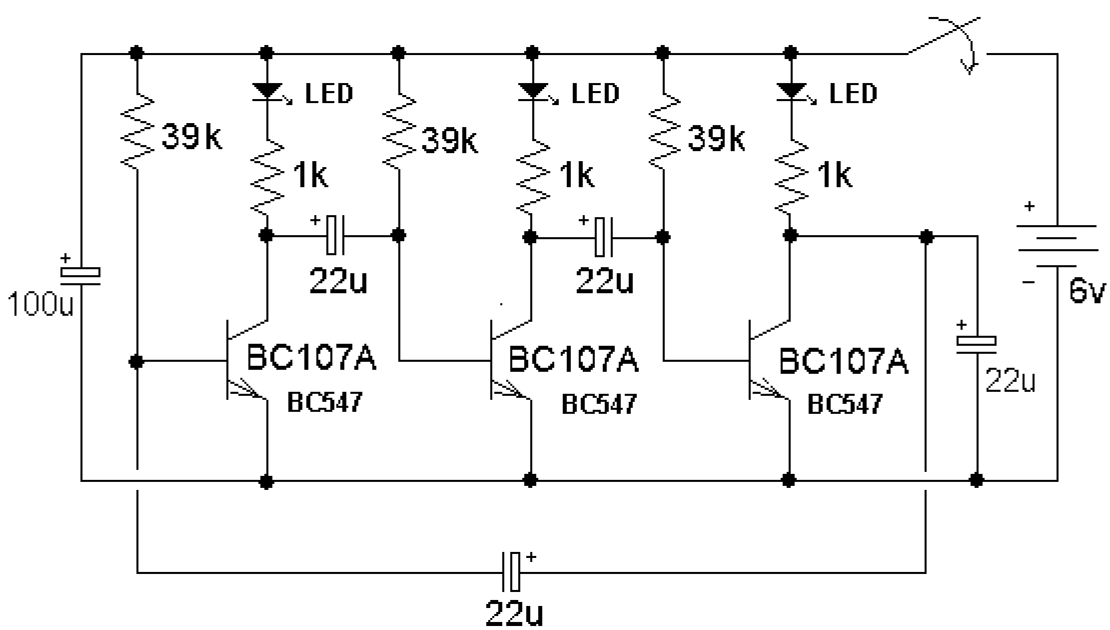
You can use almost any nut and bolt and any wire from 0.2mm to 0.5mm diameter.
The main winding has 100 turns and the feedback winding has 30 turns.

All these LED panels have inbuilt resistors so they can be connected to 12v supplies. We do not need the inbuilt resistors in this circuit however the resistors cannot be removed.

The LED strip shown in the circuit above contains 9 LEDs in groups of 3 with an inbuilt current liming resistor. The current-limiting resistor is not needed in this design but cannot be removed. You can make your own LED strip by connecting three white LEDs in series (NO current-limiting resistor is needed). You can have a total of 9 LEDs. (3 strings of 3 LEDs) or you can use any of the 12v LED panels available on eBay.
If the circuit does not work, connect the feedback wires around the other way.
The LDR is included to turn the circuit ON only at night and the emitter-follower transistor increases the ON-time to about 4 seconds.

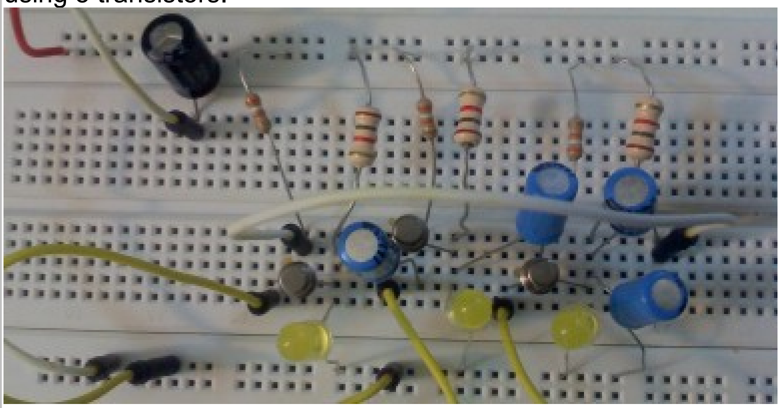
You can use old cells and make sure the supply is not higher than 9v as the LED Strip will remain illuminated because you will be supplying enough voltage to illuminate it !!
You will need to experiment with the 2k2 resistor and 2n2 to get the best illumination with the transformer you use and the supply voltage.

3-LED CHASER by Faraday s.sh_butterfly@yahoo.com



The LEDs in this circuit produce a chasing pattern similar the running LEDs display in video

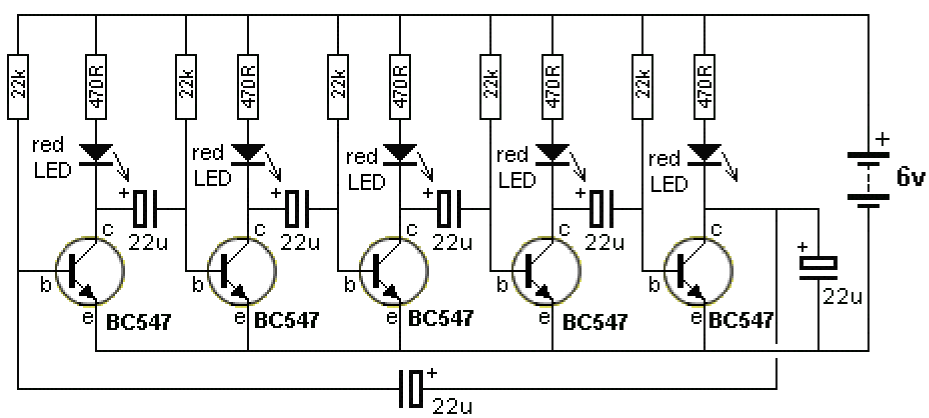
shops.
In fact the effect is called: "Running Hole." All transistors will try to come on at the same time when the power is applied, but some will be faster due to their internal characteristics and some will get a different turn-on current due to the exact value of the 22u electrolytics. The last 22u will delay the voltage-rise to the base of the first transistor and make the circuit start reliably. It is very difficult to see where the hole starts and that's why you should build the circuit and investigate it yourself. The circuit can be extended to any number of odd stages as shown in the next circuit, using 5 transistors.



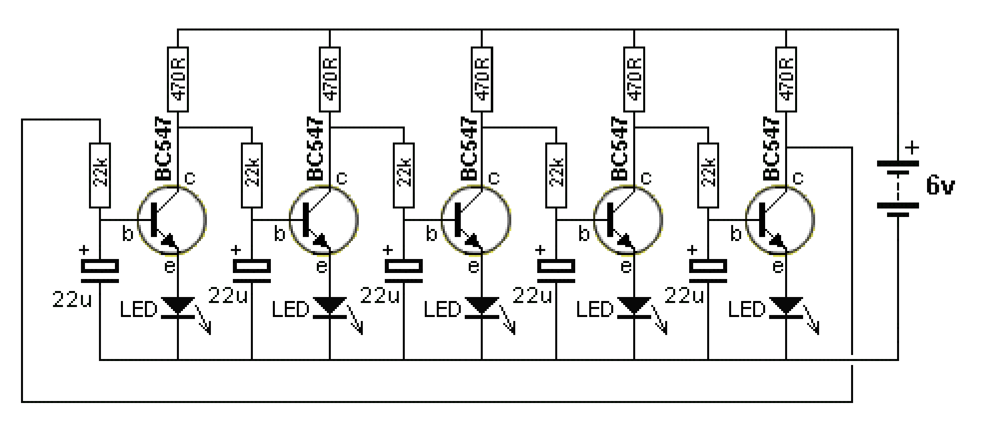
Video by Faraday: 3-LED Chaser mp4 128KB

5-LED CHASER

This is an extension of the 3-LED Chaser above.

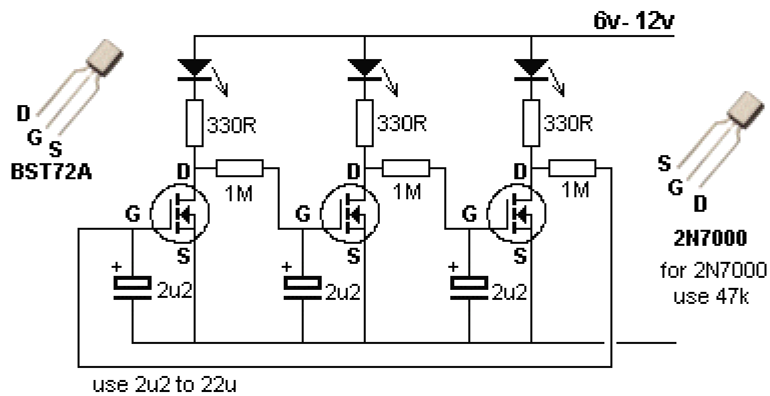


The following circuit produces a slightly different effect because the LEDs are in the emitter. You cannot mix the LED colours.

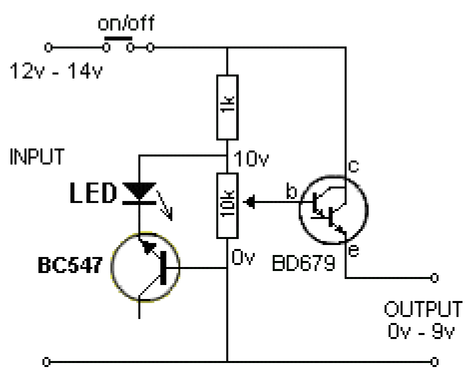


3-LED CHASER using FETs

This circuit uses FETs. This circuit has been tested with the following two FETs on 6v to 12v with red and white LEDs. The 1M resistor must be reduced to 47k for the 2N7000. Note the different pin-outs for the two FETs.

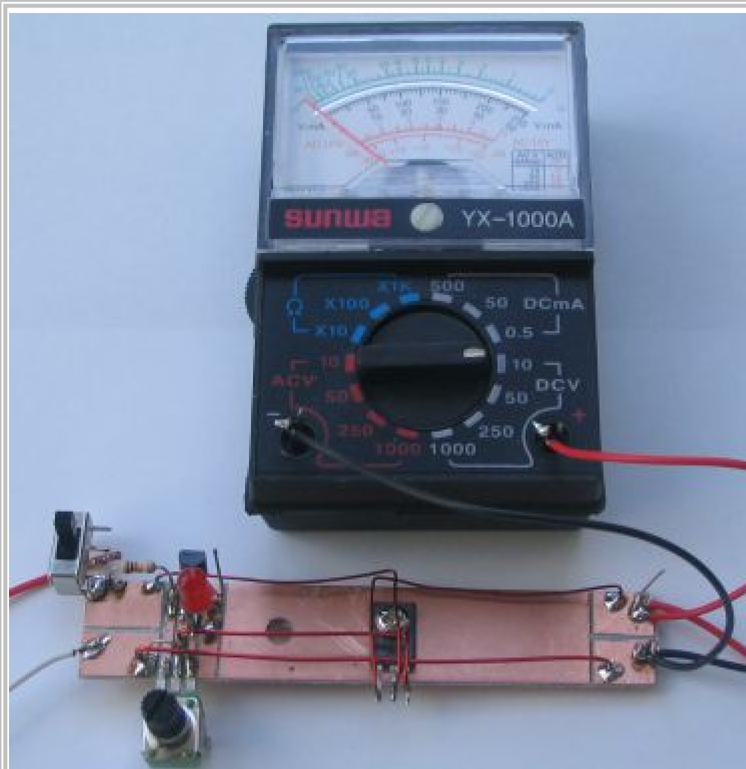


BENCH POWER SUPPLY

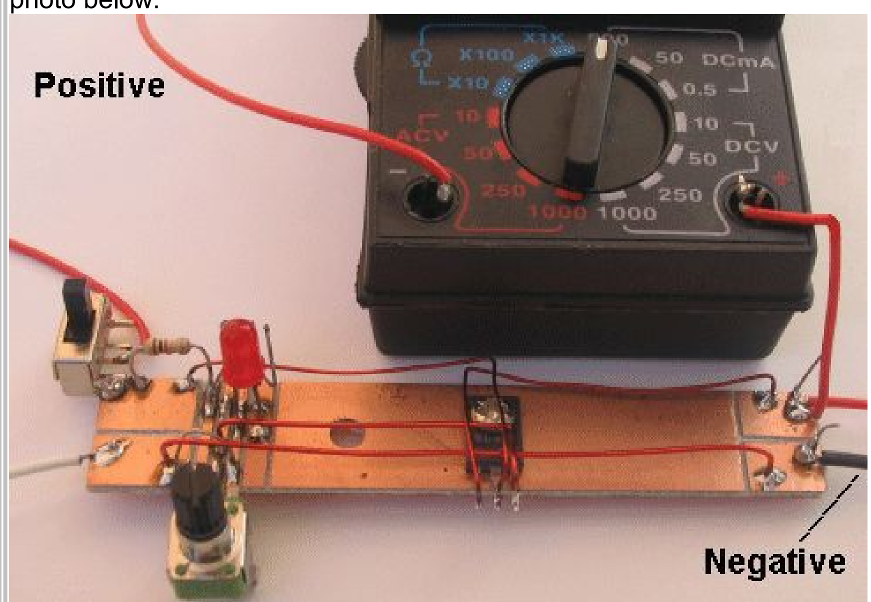


This power supply can be built in less than an hour on a piece of copper-laminate. The board acts as a heat-sink and the other components can be mounted as shown in the photo, by cutting strips to suit their placement.
The components are connected with enamelled wire and the transistor is bolted to the board to keep it cool.
The Bench Power Supply was designed to use old "C," "D" and lantern batteries, that's why there are no diodes or electrolytics. Collect all your old batteries and cells and connect them together to get at least 12v -14v.
The output of this power supply is regulated by a 10v zener made up of the characteristic zener voltage of 8.2v between the base-emitter leads of a BC547 transistor (in reverse bias) and approx 1.7v across a red LED. The circuit will deliver 0v - 9v at 500mA (depending on the life left in the cells your are using). The 10k pot adjusts the output voltage and the LED indicates the circuit is ON. It's a very good circuit to get the last of the energy from old cells.

ADDING A VOLT-METER TO THE BENCH POWER SUPPLY



A voltmeter can be added to the Bench Power Supply by using a very low cost multimeter. For less than $10.00 you can get a mini multimeter with 14 ranges, including a 10v range. The multimeter can **also** be used to monitor current by removing the negative lead and making a new RED lead, fitting it to the "—" of the multimeter and selecting the 500mA range as shown in the photo below:



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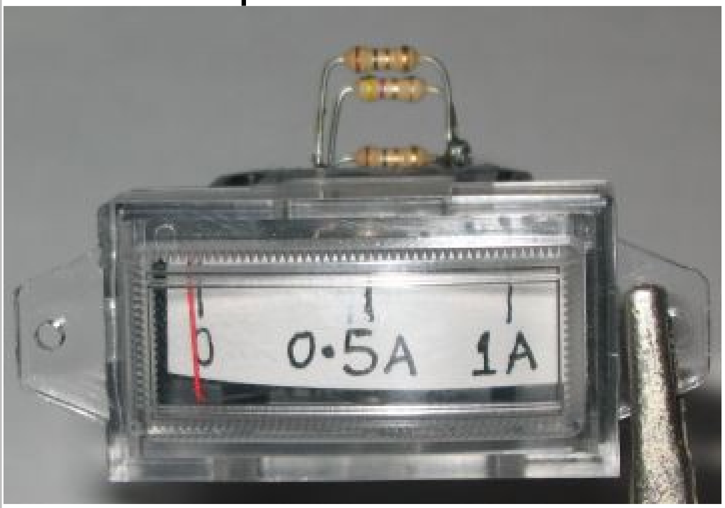
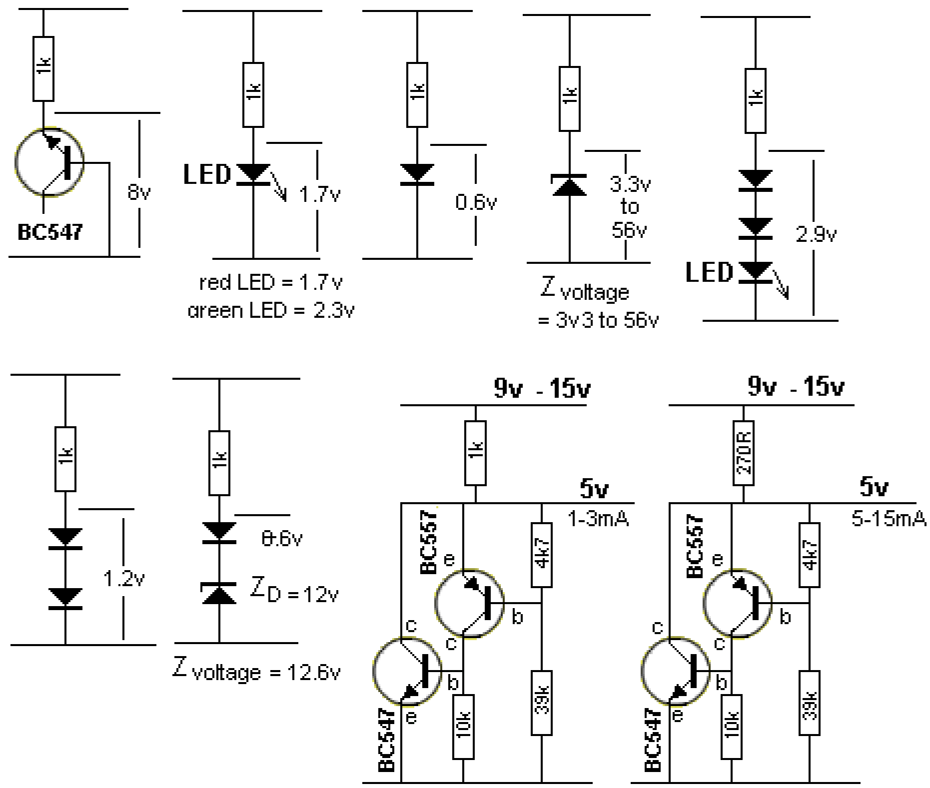
MAKING 0-1Amp meter for the BENCH POWER SUPPLY

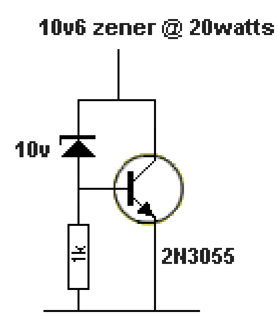


The item in the photo is called a "Movement." A movement is a moving coil with a pointer and no resistors connected to the leads.
Any Movement can be converted to an ammeter without any mathematics.
Simply solder two 1R resistors (in parallel) across the terminals of any movement and connect it in series with an ammeter on the output of the Bench Power Supply. The second ammeter provides a reference so you can calibrate the movement. Connect a globe and increase the voltage.
At 500mA, if the pointer is "up scale" (reading too high) add a trim-resistor. In our case it was 4R7.
The three shunt resistors can be clearly seen in the photo. Two 1R and the trim resistor is 4R7.
You can get a movement from an old multimeter or they are available in electronics shops as a separate item. The sensitivity does not matter. It can be 20uA or 50uA FSD or any sensitivity.

MAKING A ZENER DIODE and POWER ZENER

Sometimes a zener diode of the required voltage is not available. Here are a number of components that produce a characteristic voltage across them. Since they all have different voltages, they can be placed in series to produce the voltage you need. A reference voltage as low as 0.65v is available and you need at least 1 to 3mA through the device(s) to put them in a state of conduction (breakdown).

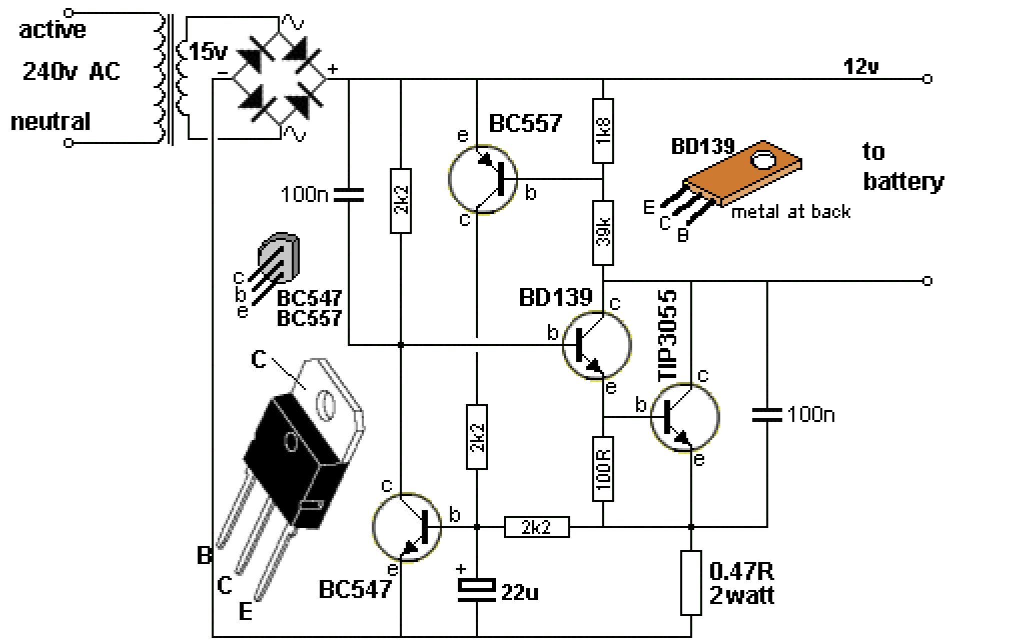




POWER ZENER

A **POWER ZENER** can be made from an ordinary zener and a transistor. The final power-zener voltage will be 0.6v higher than the zener and the wattage of the whole circuit will depend on the type of transistor used. Of course, constant use of this circuit will represent a waste of 20 watts and there are better ways to design a circuit, but it can be used to prevent a rail rising above a certain voltage and will only be used for short durations.

12v TRICKLE CHARGER



The 12v Trickle Charger circuit uses a TIP3055 power transistor to limit the current to the battery by turning off when the battery voltage reaches approx 14v or if the current rises above 2 amp. The signal to turn off this transistor comes from two other transistors - the BC557 and BC 547.

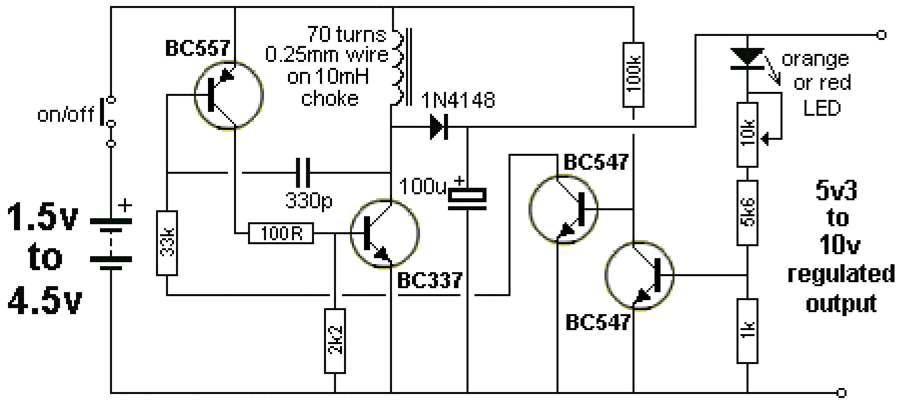
Firstly, the circuit turns on fully via the BD139 and TIP3055. The BC557 and BC 547 do not come into operation at the moment. The current through the 0.47R creates a voltage across it to charge the 22u and this puts a voltage between the base and emitter of the BC547. The transistors turn on slightly and remove some of the turn-on voltage to the BD139 and this turns off the TIP3055 slightly.

This is how the 2 amp max is created.

As the battery voltage rises, the voltage divider made up of the 1k8 and 39k creates a 0.65v between base and emitter of the BC557 and it starts to turn on at approx 14v. This turns on the BC 547 and it robs the BD136 of "turn-on" voltage and the TIP3055 is nearly fully turned off.

All battery chargers in Australia must be earthed. The negative of the output is taken to the earth pin.

1.5v to 10v INVERTER



This very clever circuit will convert 1.5v to 10v to take the place of those expensive 9v batteries and also provide a 5v supply for a microcontroller project.
But the clever part is the voltage regulating section. It reduces the current to less than 8mA when no current is being drawn from the output. With a 470R load and 10v, the output current is 20mA and the voltage drop is less than 10mV. The pot will adjust the output voltage from 5.3v to 10v.

HOW THE CIRCUIT WORKS

The circuit starts by the 100k turning on the BC547 and the BC557 gets turned ON via the 33k resistor.
This turns ON the BC337 via the 100R resistor. You will notice the "current-limiting" resistors are getting small and smaller. This is because the transistor-current is getting larger and larger and we want the resistor to pass this higher current.
Current flowing through the collector-base of the BC337 causes current to flow through the inductor. This current creates expanding flux that cuts all the turns of the inductor and produces a voltage in the OPPOSITE DIRECTION. This voltage OPPOSES the incoming voltage and very little current flows.
Over a period of microseconds, this voltage drops a microscopic amount and thus a slightly higher current will flow.
The voltage on the collector drops and this change is passed through the 330p to turn on the BC557 MORE.
This continues until the BC337 is fully turned ON (by the action of the 330p).
The 330p now charges a little more and this reduces the base current in the BC557 and it starts to turn OFF.
This action starts to turn OFF the BC337 and very soon we have both transistors fully turned OFF.
The BC337 is effectively removed from the circuit and the current flowing through the inductor stops increasing. The magnetic flux stops increasing and the voltage it produces stops IMMEDIATELY.
The magnetic flux now does not have any voltage opposing it and it starts to collapse and cut all the turns of the inductor. It does this very quickly because there is no voltage opposing its collapse.
The result is a very high voltage in the opposite direction to the applied voltage. What this means is the lower terminal of the inductor produces a voltage that is ADDED to the supply voltage.
This voltage can be as high at 100v or more, and is passed through the diode.
Even though this voltage is very high, it actually consists of a very high voltage with a very small current.
The combination of these two is called ENERGY and it flows into the 100u to charge it.
As the voltage on the 100u increases, its voltage is detected by the 4th transistor and

when it reaches 10v, the 3rd transistor is turned OFF slightly so the first two transistors are not driven as hard.
This is how a stable 10v is produced.

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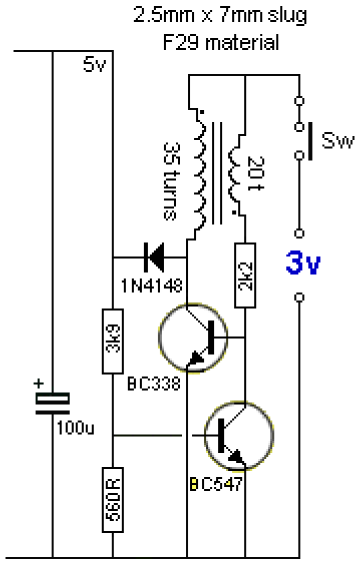
5v REGULATED SUPPLY FROM 3V



This circuit will produce a 5v regulated output from 2 cells (3v). The output current is limited to 50mA but will be ideal for many microcontroller circuits.
The output voltage is set to 5v by the 3k9 and 560R resistors, making up a voltage divider network.

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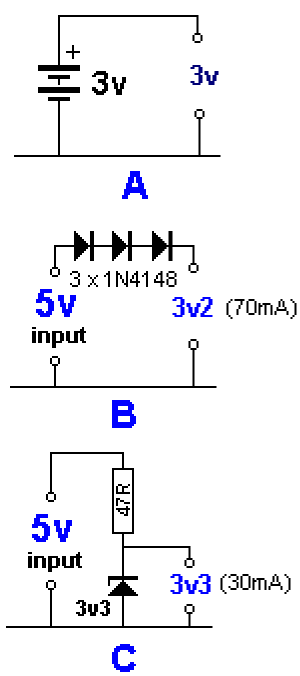
3.3v FROM 5V SUPPLY



Here are 3 ways to generate a 3.3v supply:

Circuit "A" uses two 1.5v cells. This is the cheapest and best way to create a 3v supply.

Circuit "B" uses 3 x 1N448 signal diodes to drop 1.8v and produce 3.2v on the output. The 5v supply must be regulated.

Circuit "C" produces 3.3v from a 3v3 zener. The 47R limits the output to about 30mA. The 5v can have a small ripple as the zener will create a stable 3v3 output.

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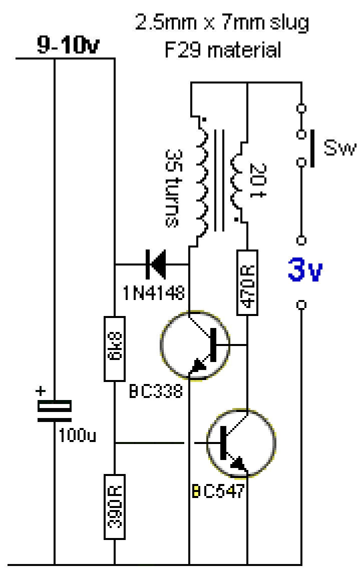
9v SUPPLY FROM 3V



You can replace a 9v battery with this circuit.
The output is about 10.4v on no load and 9.6v @30mA .
The advantage is the voltage stays over 9v for the life of the cells.
A normal 9v battery drops to 7v very quickly.
The output voltage is set to 9-10v by the 6k8 and 390R resistors. The 470R gives the circuit an idling current of about 20mA and the spikes are about 75mV.
By increasing the 470R, the quiescent current decreases but the voltage drops more when the current is 30mA.

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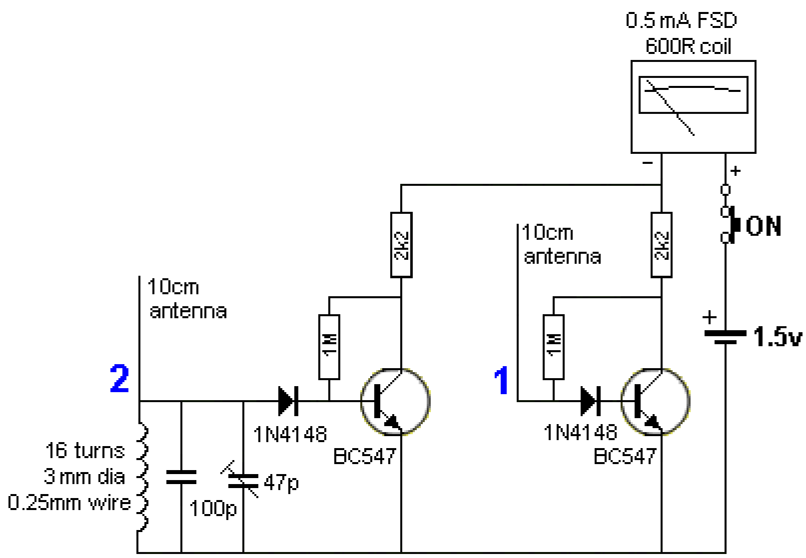
27MHz Field Strength Meter



This circuit will test 27MHz transmitters and show the transmitter is operating when the antenna is connected to point 1 and the actual frequency of transmission when the antenna is connected to point 2.
See the full project HERE.

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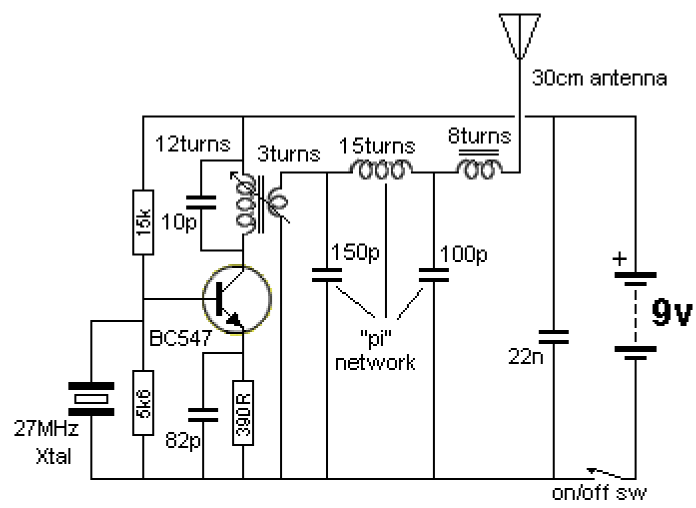
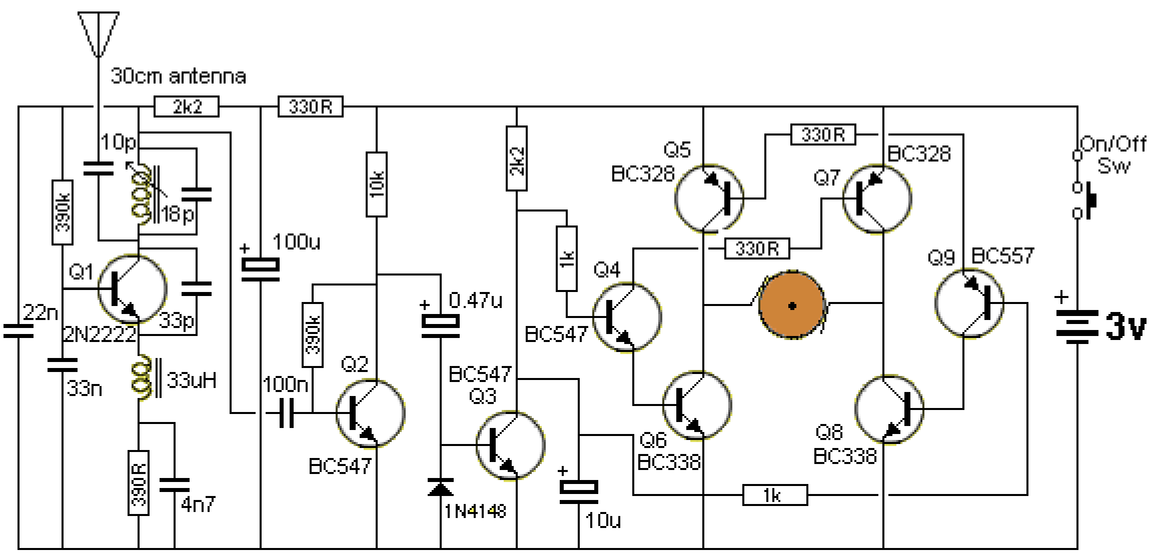


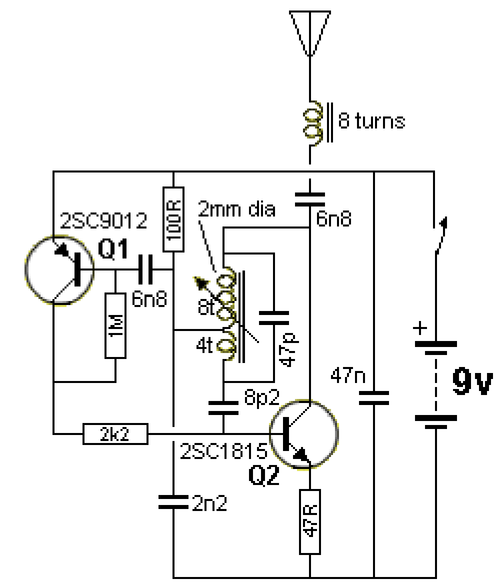
27MHz TRANSMITTER

The transmitter is a very simple crystal oscillator. The heart of the circuit is the tuned circuit consisting of the primary of the transformer and a 10p capacitor. The frequency is adjusted by a ferrite slug in the centre of the coil until it is exactly the same as the crystal. The transistor is configured as a common emitter amplifier. It has a 390R on the emitter for biasing purposes and prevents a high current passing through the transistor as the resistance of the transformer is very low. The "pi" network matches the antenna to the output of the circuit. See full description in 27MHz Links article.



27MHz RECEIVER

The 27MHz receiver is really a transmitter. It's a very weak transmitter and delivers a low level signal to the surroundings via the antenna. When another signal (from the transmitter) comes in contact with the transmission from the receiver it creates an interference pattern that reflects down the antenna and into the first stage of the receiver.
The receiver is a super-regenerative design. It is self-oscillating (or already oscillating) and makes it very sensitive to nearby signals. See full description in 27MHz Links article.

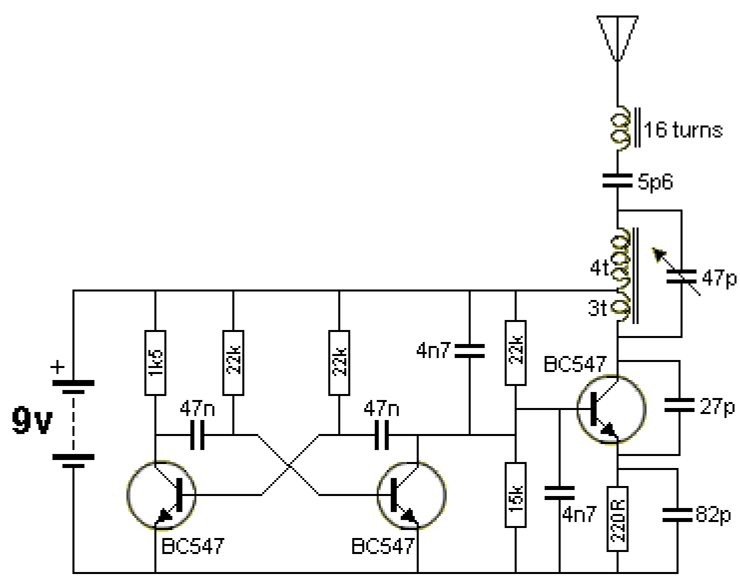


27MHz TRANSMITTER WITHOUT A CRYSTAL

A 27MHz transmitter without a crystal. When a circuit does not have a crystal, the oscillator is said to be "voltage dependent" or "voltage controlled" and when the supply voltage drops, the frequency changes.

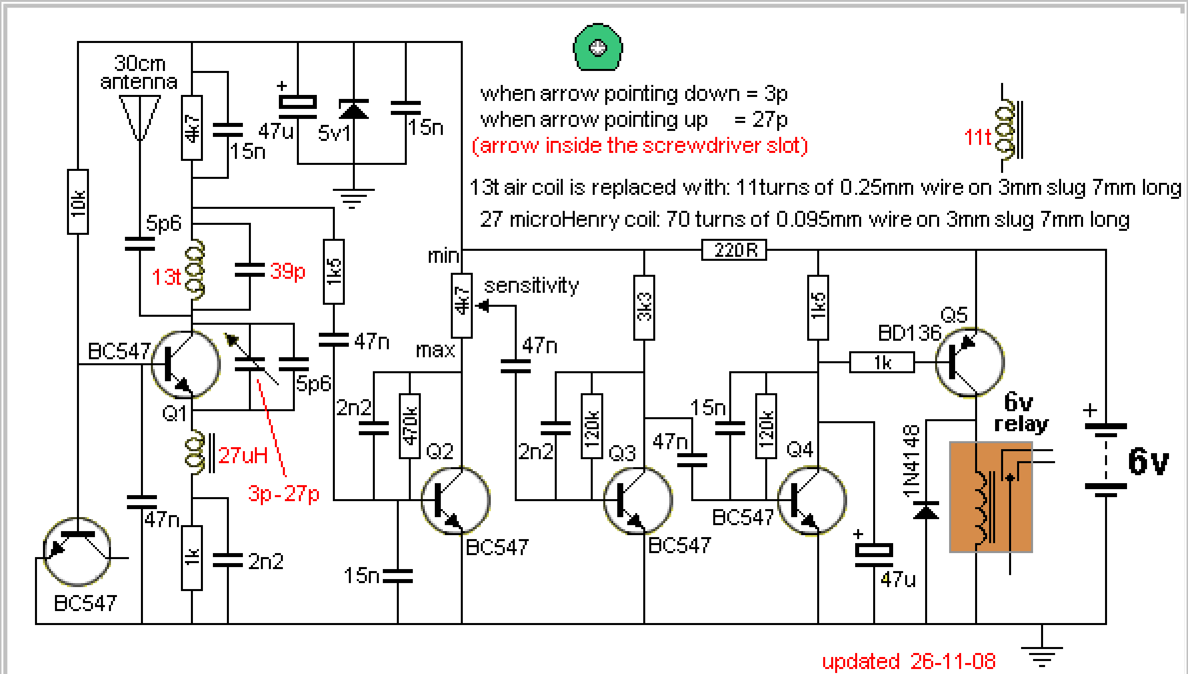
If the frequency drifts too much, the receiver will not pick up the signal. For this reason, a simple circuit as shown is not recommended. We have only included it as a concept to show how the 27MHz frequency is generated. It produces a tone and this is detected by a receiver.

See full description in 27MHz Links article.



27MHz TRANSMITTER WITH SQUARE-WAVE OSCILLATOR

The circuit consists of two blocks. Block 1is a multivibrator and this has an equal mark/space ratio to turn the RF stage on and off. Block 2 is an RF oscillator. The feedback to keep the stage operating is provided by the 27p capacitor. The frequency-producing items are the coil (made up of the full 7 turns) and the 47p air trimmer. These two items are called a parallel tuned circuit. They are also called a TANK CIRCUIT as they store energy just like a TANK of water and pass it to the antenna. The frequency of the circuit is adjusted by the 47p air trimmer. See full description in 27MHz Links article.



27MHz RECEIVER-2

This circuit matches with the 27MHz Transmitter with Square-wave Oscillator. See full description on Talking Electronics website: 27MHz Links article.
The receiver frequency is fixed. The transmitter is adjusted to suit the receiver. The 3-27p trimmer is adjusted for maximum gain (10p trimmer and 5p6 in our case) and this is a critical adjustment.
The base-emitter junction of the first BC547 sets 0.7v (as it is heavily turned on by the 10k) on the base of the oscillator Q1, and this is fixed. Q1 is very lightly turned on (due to the emitter resistor), and this makes it very sensitive when it is oscillating. Any 27MHz signal from the surroundings will upset the oscillator and any tone in the signal will be passed to the stages for amplification. The coil is 13 turns. It can be replaced with 11 turns of 0.25mm wire on 3mm dia slug 7mm long.
Although the original Russian product worked very well, our prototype did not have very good sensitivity. The circuit was very difficult to set-up.
Note: When making the 27uH inductor and checking its value on an inductance meter; if the meter does not read low values accurately, put two inductors in series. Measure the first inductor, say 100uH. The two inductors in series will be 127uH as inductors combine just like resistors in series! The result is the addition of the individual values.

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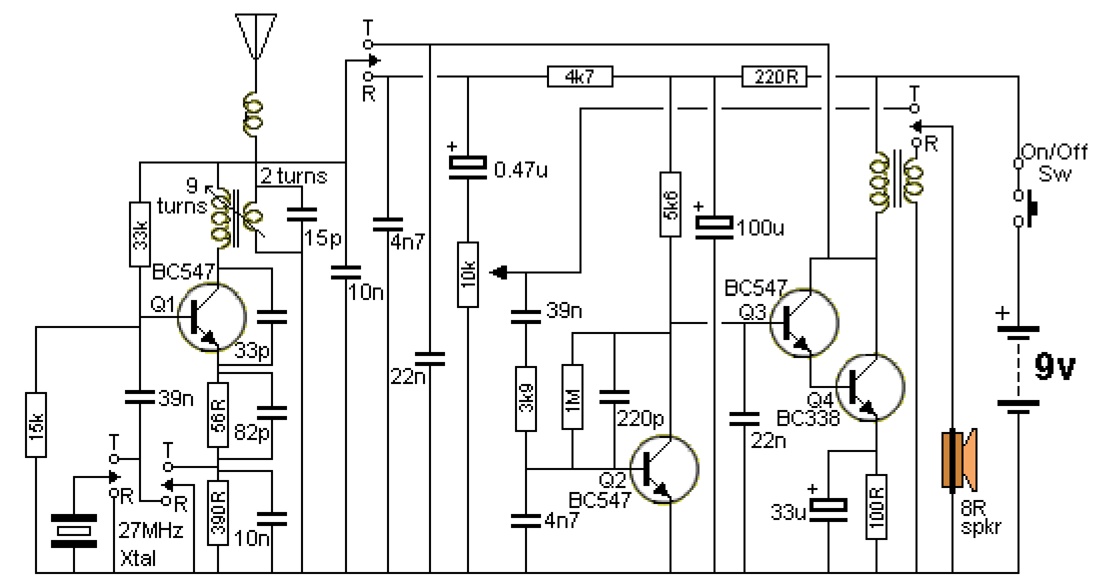
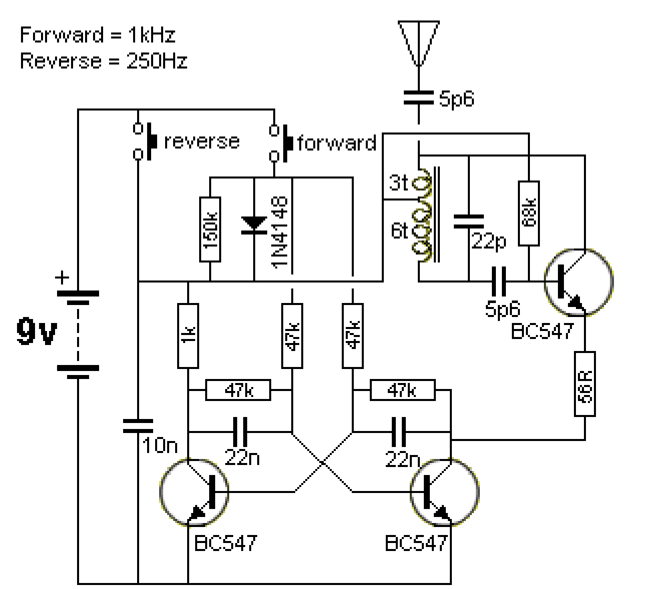


WALKIE TALKIE

Nearly all the components in the 4-transistor circuit are used for both transmitting and receiving. This makes it a very economical design. The frequency-generating stage only needs the crystal to be removed and it becomes a receiver. Next is a three transistor directly coupled audio amplifier with very high gain. The first transistor is a pre-amplifier and the next two are wired as a super-alpha pair, commonly called a Darlington pair to drive the speaker transformer. See full description in 27MHz Links article.



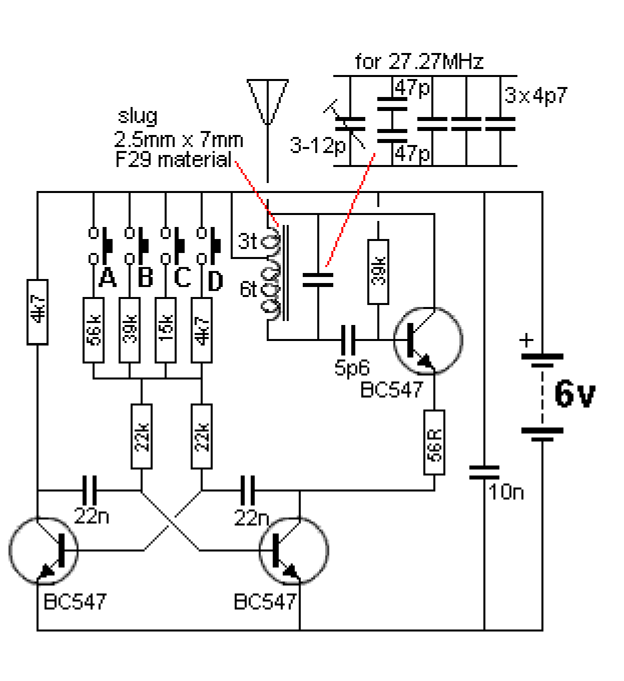
27MHz TRANSMITTER - 2 CHANNEL

This circuit does not use a crystal but has a clever feature of using the two push buttons to turn the circuit on when it is required to transmit.

The frequency of the multivibrator is determined by the value of resistance on the base of each transistor. The multivibrator is driven directly from the supply with the forward button and via a 150k for the reverse frequency.

The receiver requires a 1kHz tone for forward and 250Hz for reverse.

See full description in 27MHz Links article.



27MHz TRANSMITTER - 4 CHANNEL

This circuit uses the same number of components as the 2-Channel circuit above but has 4 channels.
The frequency of the multivibrator is determined by the value of resistance on the base of each transistor.
A 4 channel receiver has been designed by talking Electronics using a PIC12F628 micro to detect the different frequencies.
See P4 of:
2 Digit Up/Down Counter (see left index on Talking Electronics website).
2 Digit Up/Down Counter has the receiver section.

A = 500Hz B = 550Hz C = 660Hz D = 1kHz

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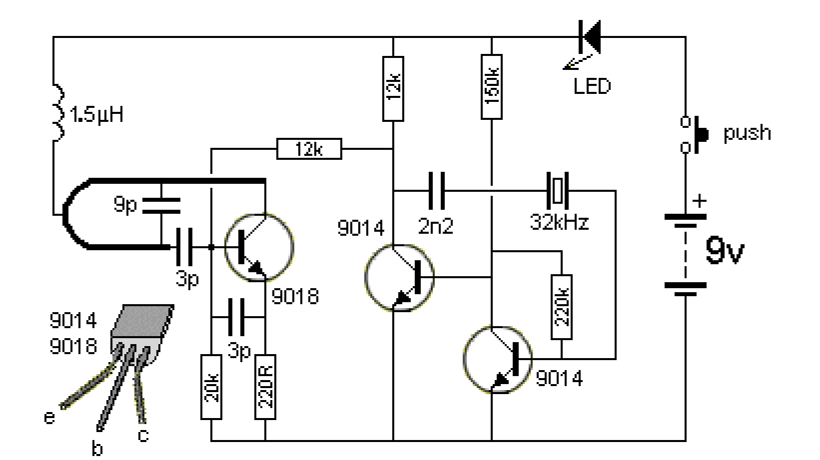

303MHz TRANSMITTER

The transmitter circuit is made up of two building blocks - the 303MHz RF oscillator and the 32kHz crystal controlled oscillator to generate a tone so the receiver does not false-trigger.
The 303MHz oscillator consists of a self-oscillating circuit made up of the coil on the PC board and a 9p (9 puff) capacitor.

See full description in Wireless Doorbell article.

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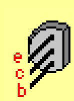
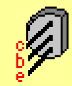
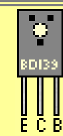
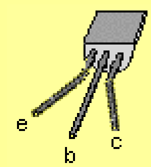
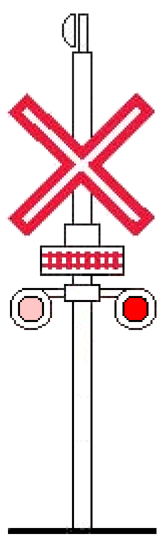
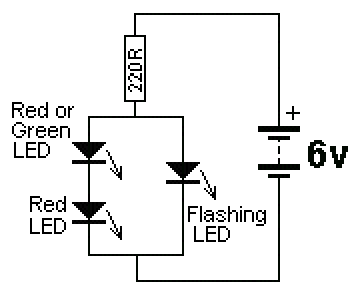
Type:		Gain:	Vbe	Vce	Current	Case
2SC1815	NPN	100	1v	50v	150mA	
2SC3279	NPN	140 to 600 @0.5A	0.75v	10v	2amp	

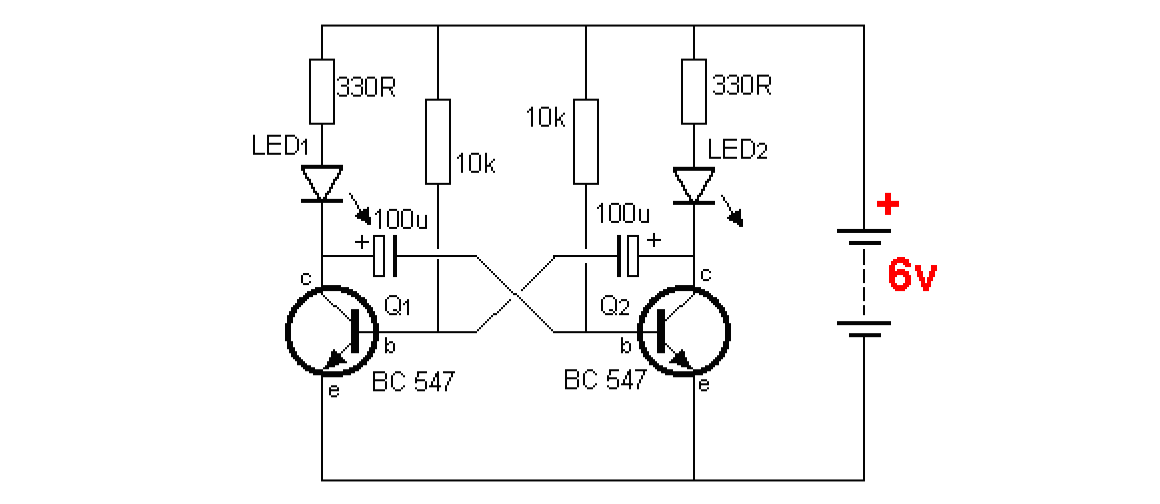
BC337 BC338	NPN	60 @300mA	0.7v	45v 25v	800mA	
BC547 BC548 BC549	NPN	70 @100mA	0.7v	45v 30v 30v	100mA	
BC557	PNP			45v	100mA	
BD139	NPN	70-100 @150mA	0.5v	80v	1.5A	
BD140	PNP	70-100 @150mA	0.5v	80v	1.5A	
2SCxxx						
8050	NPN			10v	1.5A	
8550	PNP			10v	1.5A	
9012	PNP				500mA	
9013	NPN		1v	20v	500mA	
9014	NPN				100mA	
9015	PNP				100mA	
9018	NPN	700MHz		15v	50mA	



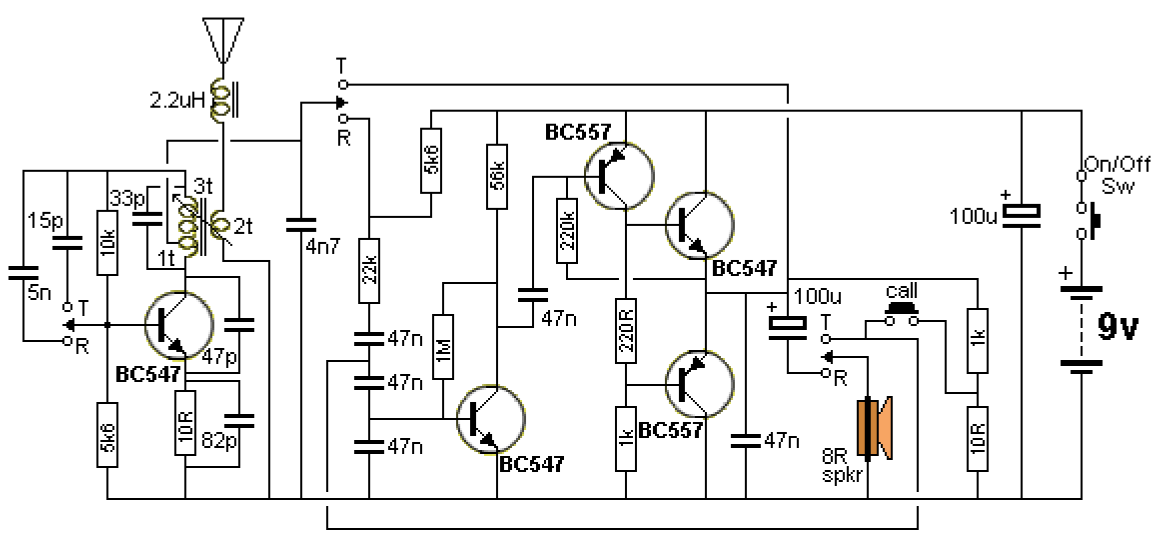


BOOM GATE LIGHTS

This simple circuit will produce flashing lights for your model railway crossing. It uses one flashing LED and one normal red LED, with a green LED hidden in the background. It can be used somewhere else on your layout but it is needed to produce a voltage drop so the two red LEDs will flash.
You cannot get a simpler circuit.
The second circuit produces the same effect but the flash-rate is more even.

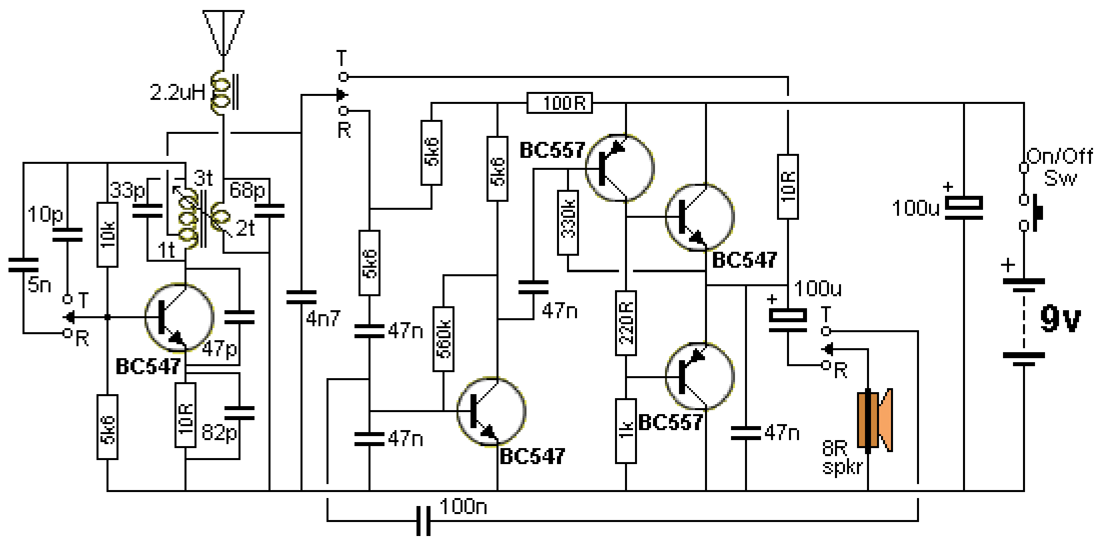


The 1/10th watt resistors used in this circuit, compared with 0.25watt resistors.



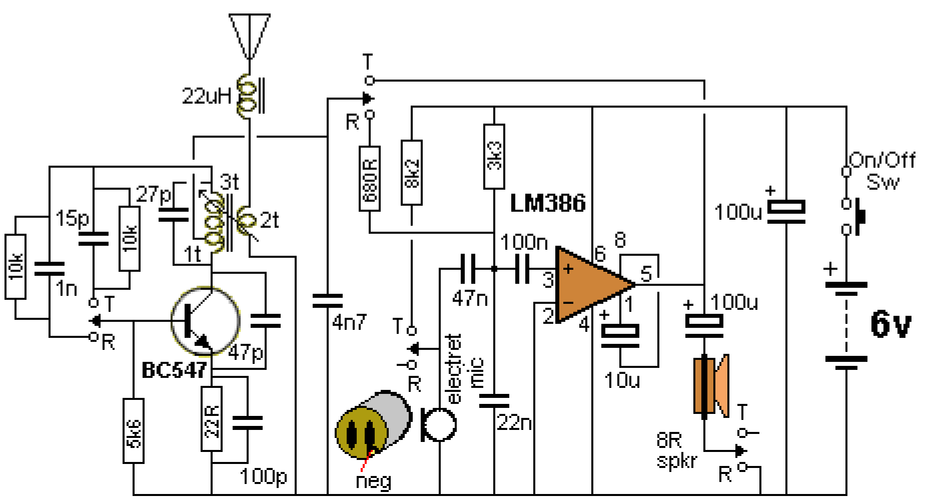
5 TRANSISTOR WALKIE TALKIE - 1

This walkie talkie circuit does not have a crystal or speaker transformer, with the board measuring just 3cm x 4cm and using 1/10th watt resistors, it is one of the smallest units on the market, for just $9.50 to $12.00. The wires in the photo go to the battery, speaker, call-switch and antenna. The most difficult component in the circuit to duplicate is the oscillator coil. See the photo for the size and shape. The coil dia is 5mm and uses 0.25mm wire. The actual full-turn or half turn on the coil is also important. Almost all 5 transistor walkie talkies use this circuit or slight variations. See the article: 27MHz Transmitters for theory on how these transmitters work - it is fascinating.



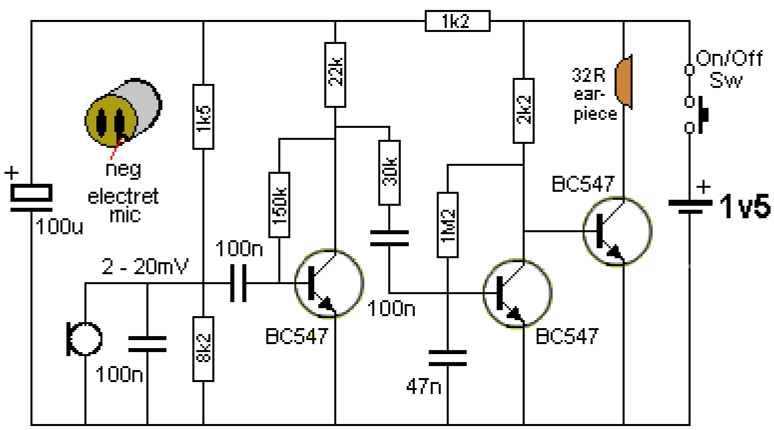
5 TRANSISTOR WALKIE TALKIE - 2

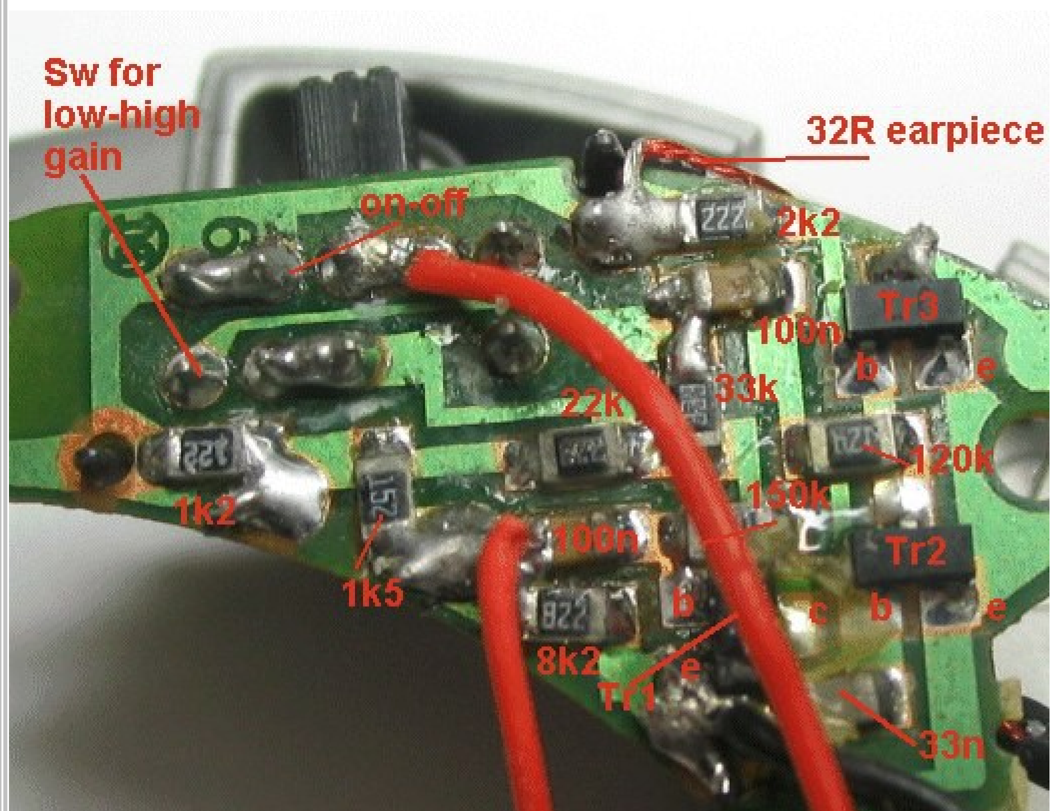
Here is another walkie talkie circuit, using slightly different values for some of the components. See the article: 27MHz Transmitters for theory on how these transmitters work.



WALKIE TALKIE with LM386

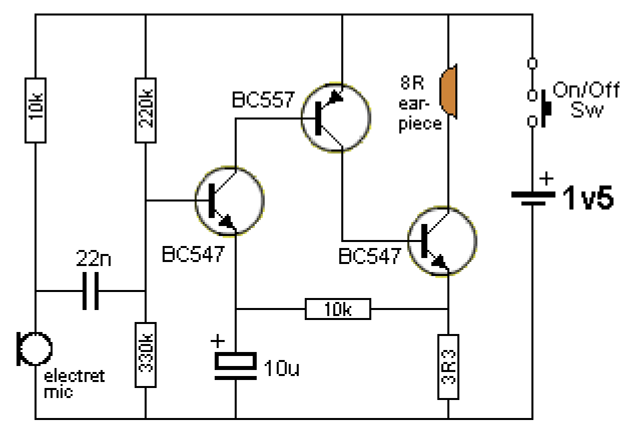
Here is a more up-to-date version of the walkie talkie, using an LM 386 amplifier IC to take the place of 4 transistors.





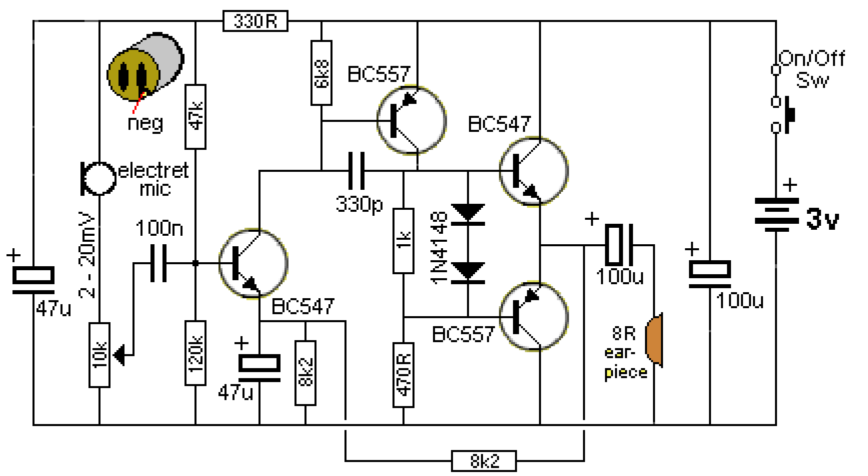
SPY AMPLIFIER

This simple circuit will detect very faint sounds and deliver them to a 32 ohm earpiece. The circuit is designed for 1.5v operation and is available from $2.00 shops for less than $5.00 The photo shows the surface-mount components used in its construction.



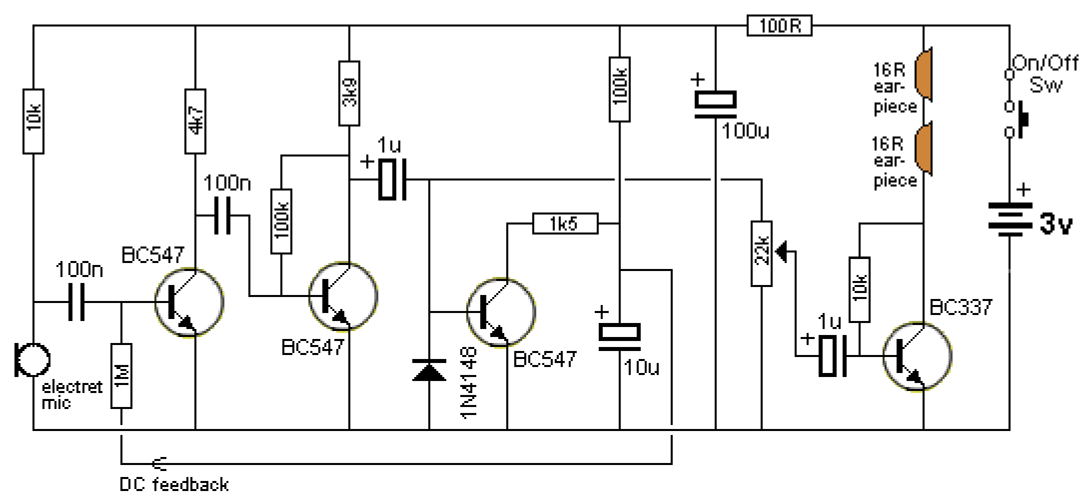
HEARING AID 1.5v SUPPLY

This simple circuit will detect very faint sounds and deliver them to an 8 ohm earpiece. The circuit is designed for 1.5v operation.



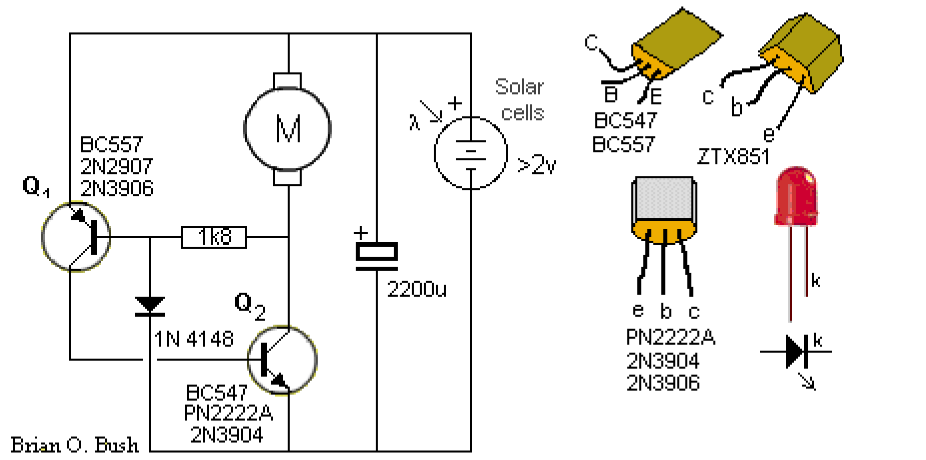
HEARING AID with PUSH PULL OUTPUT

This circuit will detect very faint sounds and deliver them to an 8 ohm earpiece. It is designed for 3v operation.



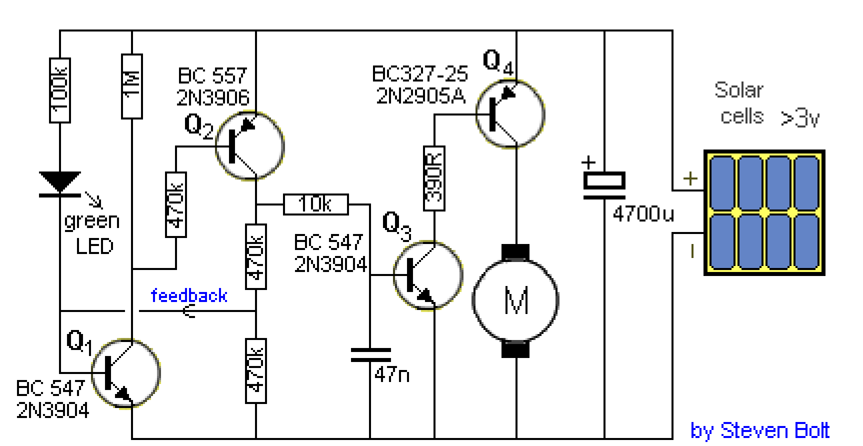
HEARING AID with CONSTANT VOLUME

This is a very handy circuit as it provides constant volume. It is designed for 3v operation.



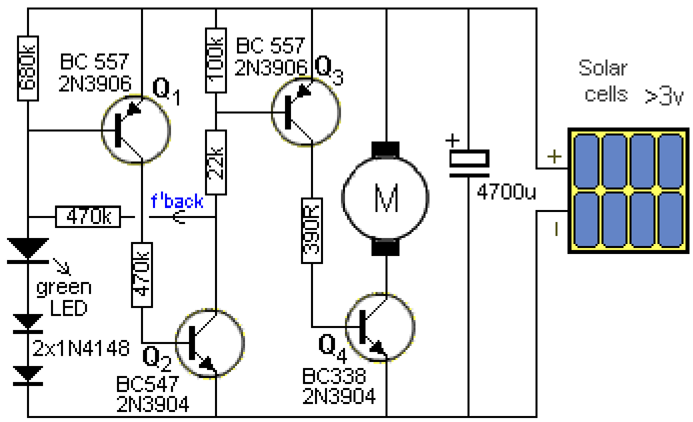
SOLAR ENGINE

This circuit is called Type-1 SE. Low current from a solar cell is stored in a large capacitor and when a preset voltage-level is reached, the energy from the capacitor is released to a motor.
For full details on how the circuit works and how to modify it, see:
http://www.talkingelectronics.com/projects/Robots/Page2.html



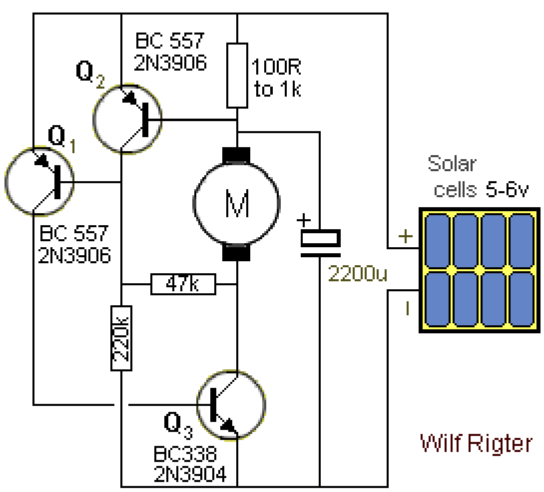
SUN EATER-I

An improved design over Solar Engine circuit above. It has a clever 2-transistor self-latching arrangement to keep the circuit **ON** until the voltage drops to 1.5v. The circuit turns on at 2.8v. This gives the motor more energy from the electrolytic at each "pulse." For full details on how the circuit works and how to modify it, see:
http://www.talkingelectronics.com/projects/Robots/Page2.html



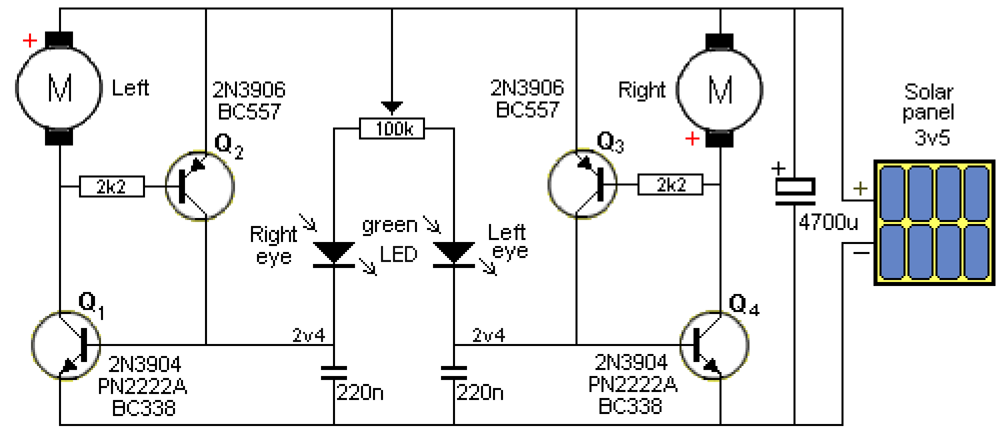
SUN EATER-1A

This circuit is an improvement on the **Sun Eater I** shown above. It works exactly the same except the slight re-arrangement of the components allows an NPN power transistor to be used. One less resistor is needed and one less capacitor but two extra diodes have been added to increase the upper turn-on voltage.
For full details on how the circuit works and how to modify it, see:
http://www.talkingelectronics.com/projects/Robots/Page2.html



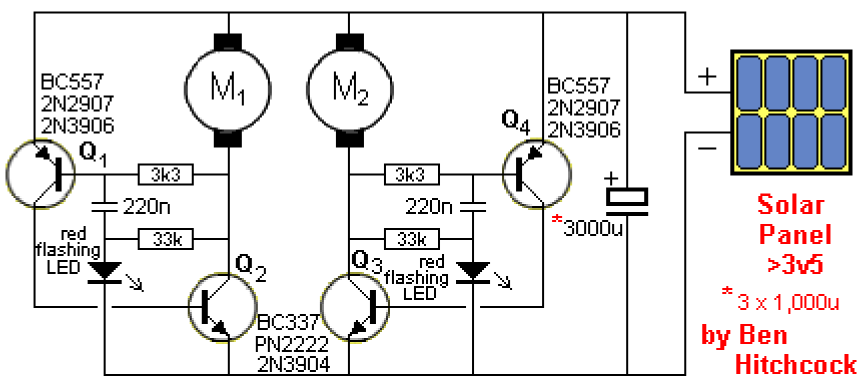
SOLAR ENGINE Type-3

Type-3 circuits are **current controlled** or current-triggered. This is another very clever way of detecting when the electrolytic has reached its maximum charge.
At the beginning of the charge-cycle for an electrolytic, the charging current is a maximum. As the electrolytic becomes charged, the current drops. In the type-3 circuit, the charging current passes through a 100R resistor and creates a voltage drop. This voltage is detected by a transistor (Q2) and the transistor is turned ON.
This action robs transistor (Q1) from turn-on voltage and the rest of the circuit is not activated. As the charging current drops, Q2 is gradually turned off and Q1 becomes turned on via the 220k resistor on the base.
This turns on Q3 and the motor is activated. The voltage across the storage electrolytic drops and the current through the 100R rises and turns the circuit off. The electrolytic begins to charge again and the cycle repeats. For full details on how the circuit works and how to modify it, see:
http://www.talkingelectronics.com/projects/Robots/Page2.html



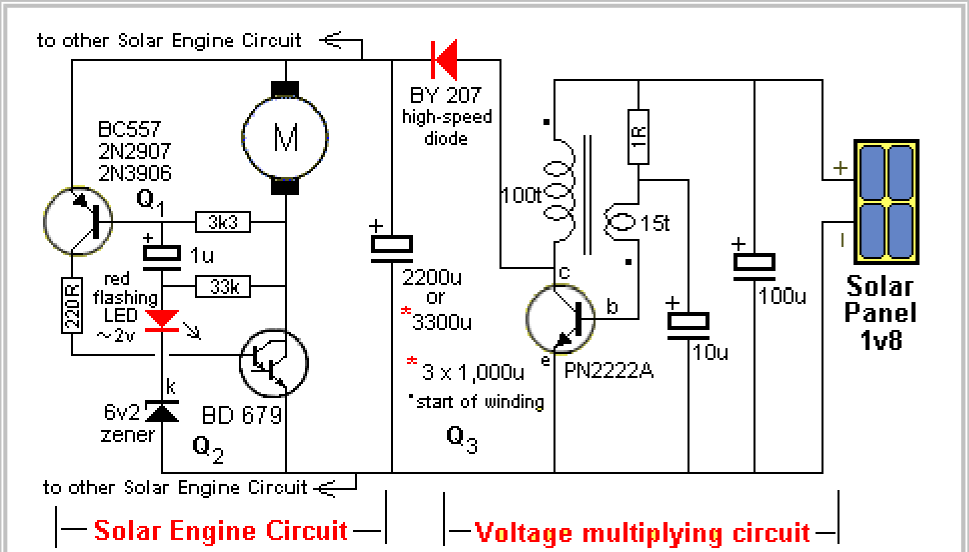
SOLAR PHOTOVORE

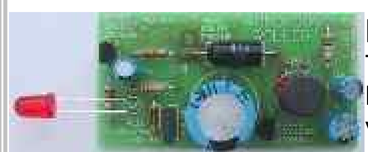
The green LEDs cause the Solar Engine on the opposite side to fire and the **Solar Photovore** turns toward the light source. The motors are two pager "vibe" motors with the weights removed. The 100k pot on the "head" balances the two Solar Engines. If you cannot get the circuit to work with green LEDs, use photo-transistors. For full details on how the circuit works and how to modify it, see:
http://www.talkingelectronics.com/projects/Robots/Page4.html



FRED Photopopper (Flashing LED)

It is a Photopopper using low-cost components. It uses two red or green flashing LEDs to turn the circuit **on** when the voltage across the electrolytic has reached about 2.7v. The flashing LEDs change characteristics according to the level of the surrounding light and this turns the circuit into phototropic. For full details on how the circuit works and how to modify it, see:
http://www.talkingelectronics.com/projects/Robots/Page6.html

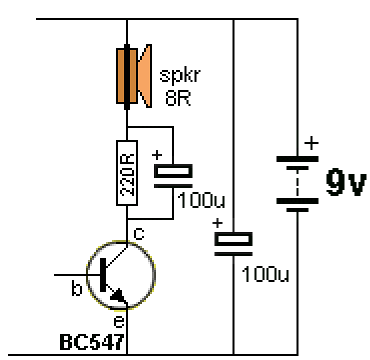




ROBO ROLLER

The circuit consists of two building blocks. The Photopopper circuit and a voltage multiplying (or voltage increasing) circuit from a **Solar Charger** project.

For full details on how the circuit works and how to modify it, see: http://www.talkingelectronics.com/projects/Robots/Page7.html

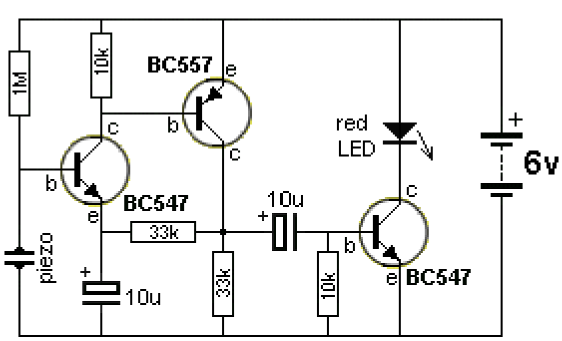


SIGNAL BY-PASS

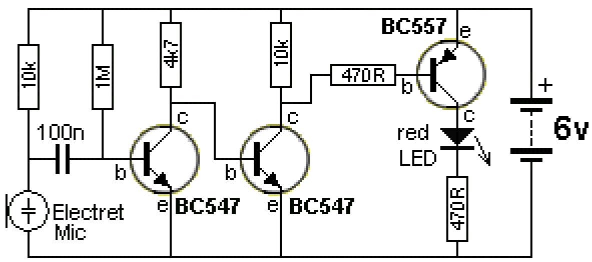
This circuit allows a class-A amplifier to drive a low impedance speaker and has a low quiescent current. The 220R in series with the speaker limits the "wasted" current to about 20mA max as the transistor is generally biased at mid-voltage. However the transistor will be almost directly driving the speaker when a signal is being processed and the only limitation is the ability of the 220R to discharge the 100u during each cycle.

The circuit is called a signal by-pass as the signal by-passes the 220R and drives the speaker directly (via the 100u).

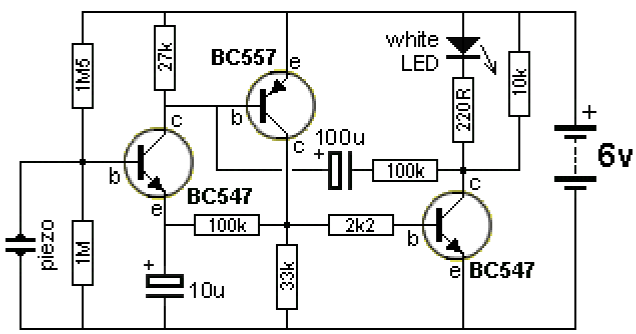
SOUND-TO-LIGHT



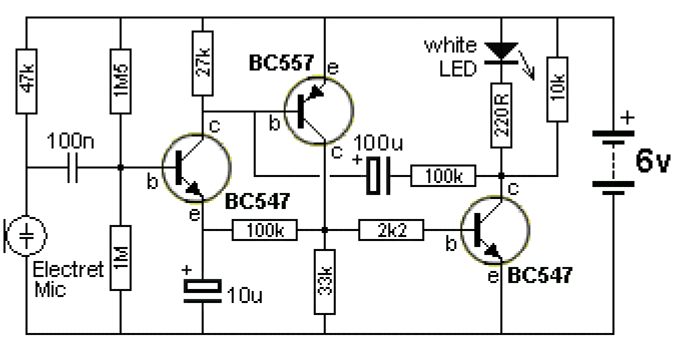
The LED illuminates when the piezo diaphragm detects sound.
Some piezo diaphragms are very sensitive and produce 100mV when whistling at 50cm. Others produce 1mV. You must test them with a CRO.
The sensitivity of the diaphragm will determine the sensitivity of the circuit.
The following circuit uses an electret microphone:



CLAP SWITCH - see also VOX



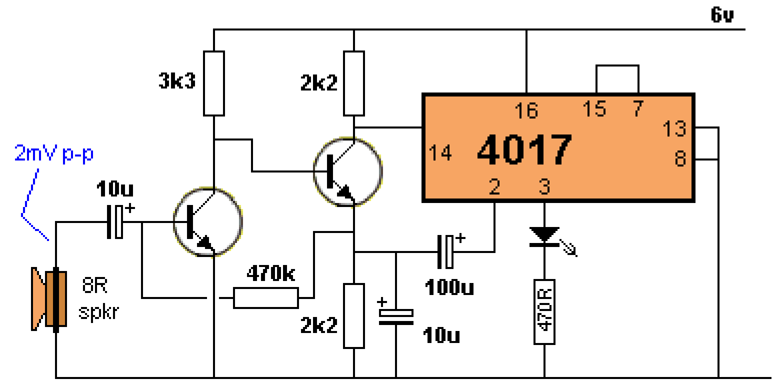
SOUND-TO-LIGHT with Delay
By re-arranging the components slightly from the previous circuit, we create a 15 second illumination of the LED. It will be illuminated with the clap of the hands.
The quiescent current is about 20uA, allowing 4 AA cells to last a long time.
The circuit takes about 20 seconds to reset after the LED goes out.
The 100u discharges through the 27k, 100k and 10k resistors.
The circuit can also be designed to accept an electret microphone:

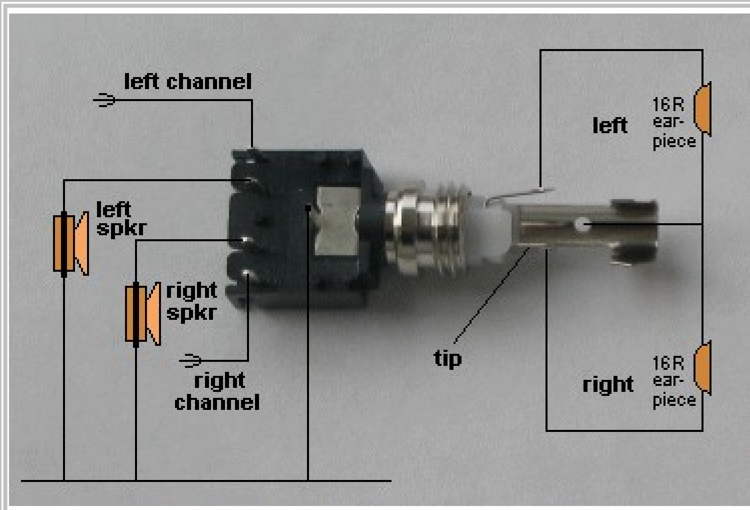


CLAP SWITCH "ON-OFF"

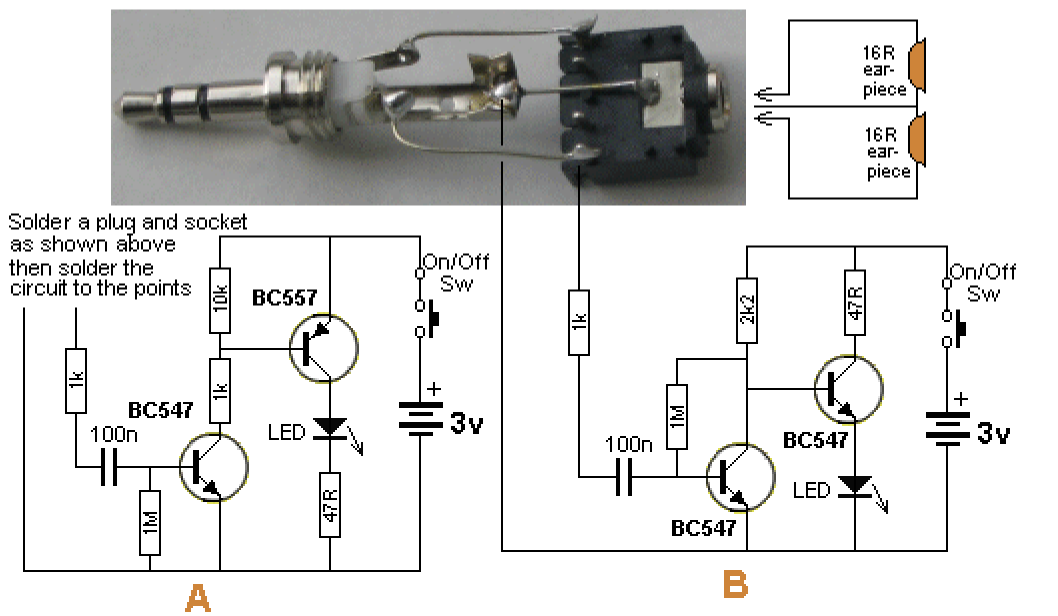
This circuit turns the LED ON with a clap or short whistle. And a further clap turns it OFF. It uses a speaker as a microphone and the

fourth output of the 4017 is used to reset the chip. The 100u on pin 2 upsets the amplifier and prevents it clocking the chip, until the electro either charges or discharges. A buffer transistor can replace the LED to operate a relay. It only requires 2mV signal to activate the circuit.





Above: **A 3.5mm switched stereo plug and socket wiring.**



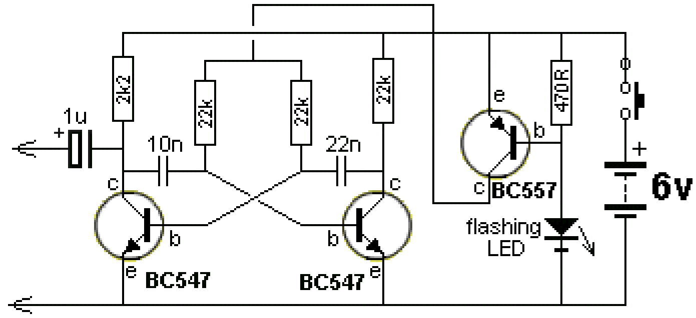
MUSIC-TO-COLOUR

The LED illuminates when the circuit detects a high amplitude waveform. It can be connected to a "Walkman" or mini radio with earphones. A second channel can be connected to produce a stereo effect. Circuit A consumes less current as the LED is off when no audio is detected. Circuit B pulses the LED brighter when audio is detected.

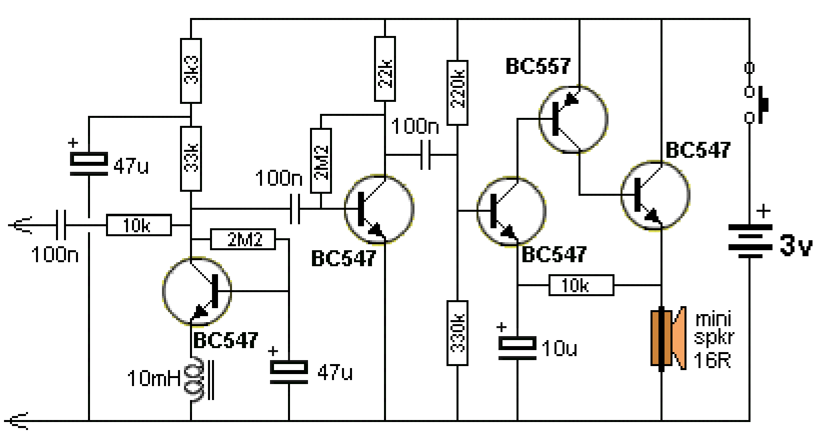
The transmitter is built on a small length of PC board, cut into lands with a file. The photo clearly shows how all the components are mounted and how the board is fitted into a toothbrush holder. The flashing LED shows the unit is ON and serves to control the beep-beep-beep of the circuit. The flashing LED is not an ordinary LED.
You cannot use an ordinary LED. It must be a FLASHING LED as this type of LED has a built-in resistor and a chip to make the LED flash.
The circuit does not make the LED flash, the LED makes the circuit beep-beep-beep due to the on-off from the chip inside the LED.
One constructor used an ordinary LED - and BANG! That's why we are the first in the world to create

a symbol for a flashing LED. The extra bar represents the chip inside the LED.

This is the professional unit



TRANSMITTER CIRCUIT



The receiver circuit is a high-gain amplifier and produces constant background noise so the slightest magnetic field can be detected.
The 10mH choke can be any value but the largest number of turns on the core is best.
The mini speaker can be a 16R earpiece but these are not as loud as a mini speaker.
Quiescent current is 50mA so the on-off switch can be a push-button.

RECEIVER CIRCUIT

CABLE TRACER

Why pay $100 for a cable tracer when you can build one for less than $10.00! This type of tracer is used

by telephone technicians, electricians and anyone laying, replacing or wiring anything, using long cables, such as intercoms, television or security.
Our cable tracer consists of two units. One unit has a multivibrator with an output of 4v p-p at approx 5kHz. This is called the transmitter. The other unit is a very sensitive amplifier with capacitive input for detecting the tone from the transmitter and a magnetic pickup for detecting magnetic lines of force from power cables carrying 240v. This is called the receiver. The circuit also has an inductive loop, made up of a length of wire, to pick up stray signals from power cables, so if one detector does not detect the signal, the other will. Our circuit is nothing like that in the professional unit shown above.

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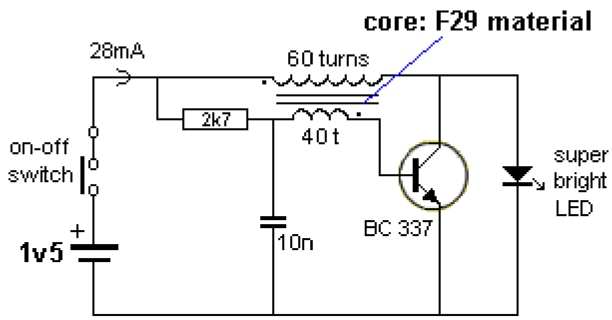

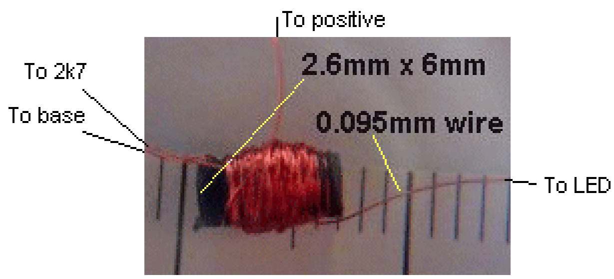

Transformer Details

LED TORCH with 1.5v SUPPLY

This simple circuit will illuminate a super-bright white LED to full brightness with 28mA from a 1.5v cell. The LED is 20,000mcd (20cd @ 15° viewing angle) and has an output of approx 1lumen.
The transformer is wound on a small ferrite slug 2.6mm dia and 6mm long. It is made from F29 ferrite material as the circuit operates at a high frequency (100kHz to 500kHz).
The efficiency of the circuit revolves around the fact that a LED will produce a very high output when delivered pulses, but the overall current will be less than a steady DC current.
BC 337 has a collector-emitter voltage of 45v. (BC338 has 25v collector-emitter voltage rating.)
The voltage across the transistor is no more than 4v as the LED absorbs the spikes. Do not remove the LED as the spikes from the transformer will damage the transistor.
The circuit will drive 1 or 2 while LEDs in series.

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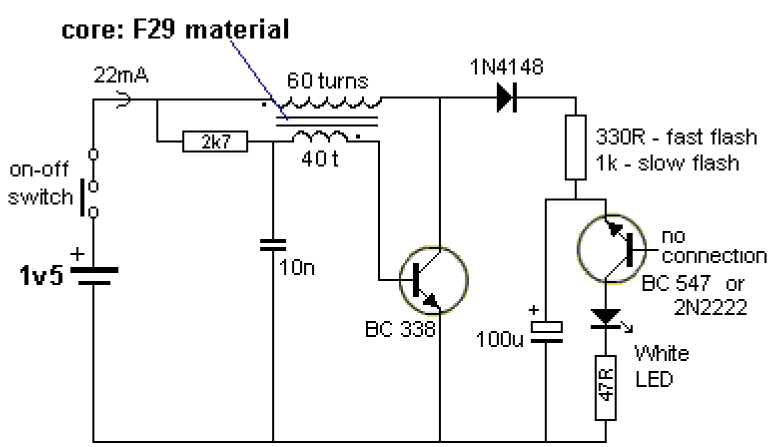


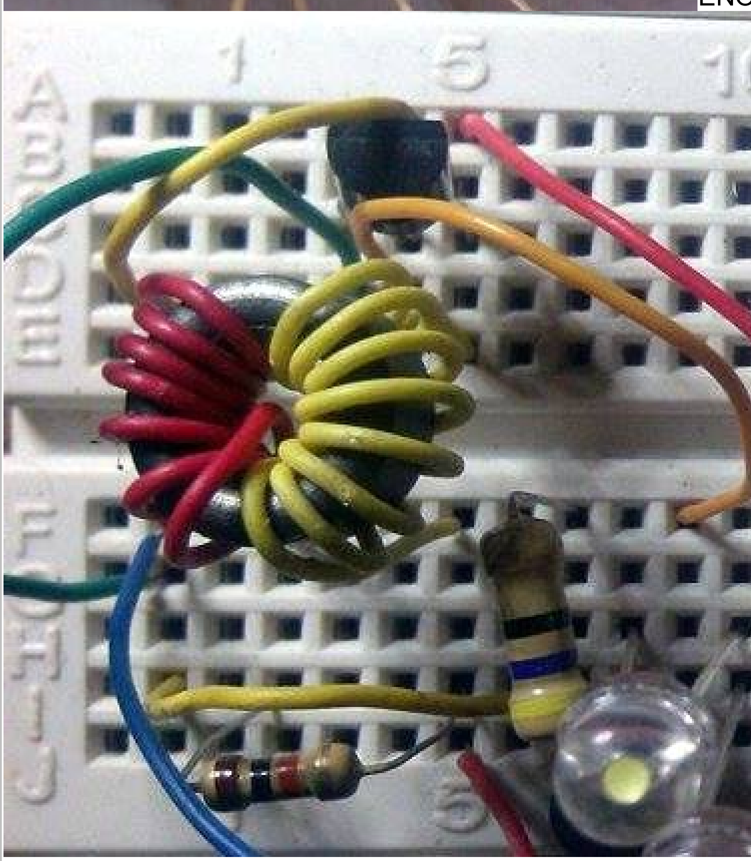
WHITE LED FLASHER

This circuit will flash a super-bright white LED from a 1.5v cell.
The transformer is wound on a small ferrite slug 2.6mm dia and 6mm long as shown in a project above.
The circuit uses the zener characteristic of the reverse-base-emitter junction of a BC 547 to pass current and flash the LED.

-

USING A TOROID INDUCTOR

Most of **our** circuits use a ferrite rod and NOT a TOROID. A toroid is a circular core (sometimes called a doughnut or torus or ring or annulus) and is actually the most efficient type of ferrite core because none of the flux is lost to the outside surroundings.
BUT if you use a toroid, you MUST work out the amount of flux you will be generating when the transistor is turned ON and this will give you the flux density in the toroid.
But this is a very difficult thing to do.
If you deliver more flux than the toroid can accept, the expanding flux will not increase at this point in time and the current taken (supplied or delivered) by the transistor will increase ENORMOUSLY and the transistor will be DESTROYED.



If you use a ferrite rod, the flux will be lost to the outside air (out the end of the rod) and the abrupt saturation-point will NOT be generated.
This means a ferrite rod is a much-more "sloppy" or "loose" or "accommodating" component and is much easier to incorporate into a circuit that has not been mathematically designed.
If you want to use a toroid, the only way to "design a circuit" that does not "self-destroy" is
to add a lot more turns and gradually remove a few of the turns while feeling the output transistor for temperature-rise or measure the current taken by the circuit.
Sometimes the number of turns will be reduced to 7 turns plus 7 turns for some of the circuits driving LEDs in the boost converters shown below.

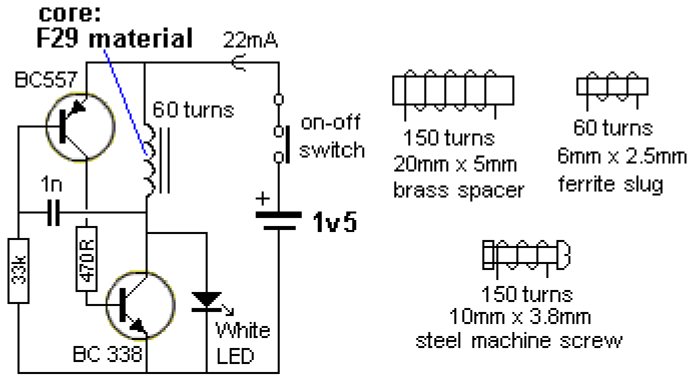
Why only 7 turns for a toroid?

As the transistor turns ON, the 7 turns produces much less flux than 30 turns and the transistor can turn on for a much longer period of time. When it is fully turned ON, the core is just at the point of being fully saturated. At this instant, the flux no-longer expands (increases) and thus the voltage produced in the feedback winding ceases. This is when the "increasing" part of the cycle stops, and the "turn-off" part of the cycle starts.
This means the current through the transistor is only a maximum for a very short period of time.

That's why you have to experiment yourself and it's only when you get the circuit to work perfectly, that you will LEARN ELECTRONICS.

The workings of an inductor are much more complex than you think.

1v5 WHITE LED DRIVER



WHITE LED DRIVER

This circuit will drive a super-bright white LED from a 1.5v cell.
The 60 turn inductor is wound on a small ferrite slug 2.6mm dia and 6mm long with 0.25mm wire.
The main difference between this circuit and the two circuits above is the use of a single winding and the feedback to produce oscillation comes from a 1n capacitor driving a high gain amplifier made up of two transistors.
The feedback is actually positive feedback via the 1n and this turns on the two transistors more and more until finally they are fully turned on and no more feedback signal is passed though the 1n. At this point they start to turn off and the signal through the 1n turns them off more and more until they are fully turned off.
The 33k turns on the BC557 to start the cycle again.

If you do not have a ferrite slug, the inductor can be made from a machine screw 10mm long and about 3-4mm dia. Wind 150 turns of 0.25mm wire. Or you can use a brass ferrule 20mm long x 5mm. Wind 150 turns.
RESULTS for the same brightness:
Slug: 21mA
Brass Spacer: 18mA
Machine screw: 14mA
Isn't this a SURPRISE!

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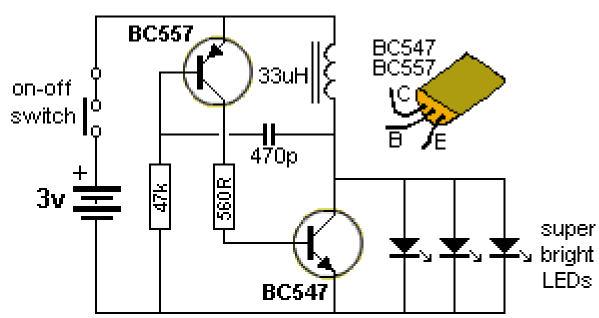

LED TORCH - 3v Supply

This circuit will drive up to 3 high-bright white LEDs from a 3v supply. (It will also work from 1.5v)
The inductor consists of 50 turns on a 1.6mm dia ferrite slug using 0.1mm enamelled wire.
This circuit can use a ready-made 33uH choke, making it suitable for mass production

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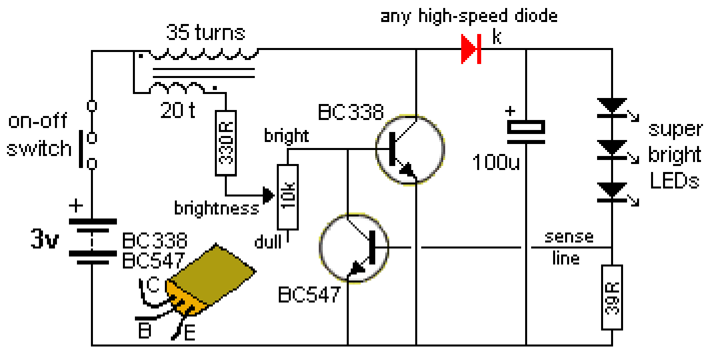

LED TORCH with ADJUSTABLE BRIGHTNESS

This circuit will drive up to 3 high-bright white LEDs from a 3v supply. The circuit has a pot to adjust the brightness to provide optimum brightness for the current you wish to draw from the battery.
The transformer is wound on a ferrite slug 2.6mm dia and 6mm long as shown in the LED Torch with 1.5v Supply project.
This circuit is a "Boost Converter" meaning the supply is less than the voltage of the LEDs. If the supply is greater than the voltage across the LEDs, they will be damaged.

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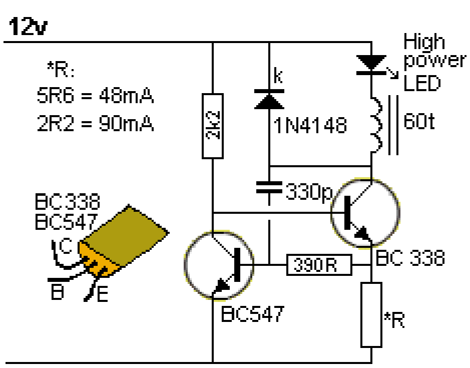

Inductor: 60 turns on 10mm ferrite rod, 15mm long.

BUCK CONVERTER for HIGH-POWER LED 48mA to 90mA

This circuit is a "Buck Converter" meaning the supply is greater than the voltage of the LED. It will drive 1 high-power white LED from a 12v supply and is capable of delivering 48mA when R = 5R6 or 90mA when R = 2R2.
The LED is much brighter when using this circuit, compared with a series resistor delivering the same current. But changing R from 5R6 to 2R2 does not double the brightness. It only increases it a small amount.
The inductor consists of 60 turns of 0.25mm wire, on a 15mm length of ferrite rod, 10mm diameter.
Frequency of operation: approx 1MHz.
The circuit is not designed to drive one 20mA LED.
This circuit draws the maximum for a BC 338.

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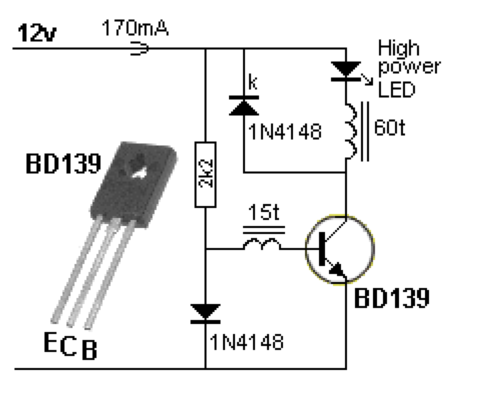
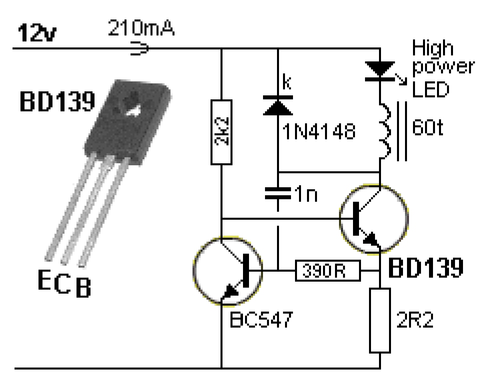


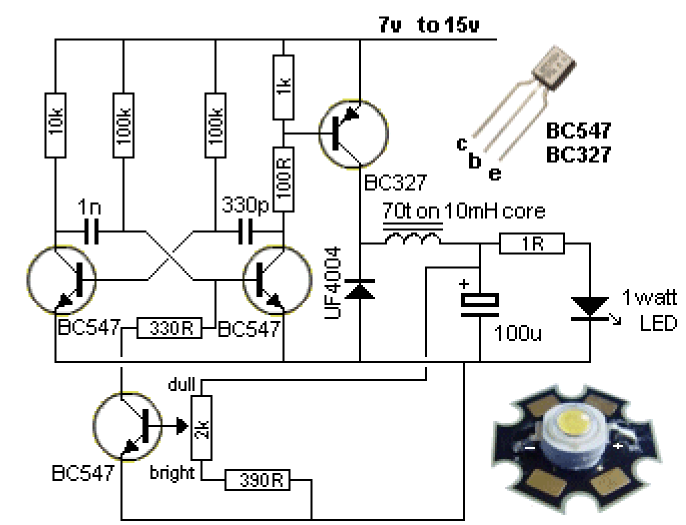
BUCK CONVERTER for HIGH-POWER LED 170mA

This circuit is slightly simpler than above but it does not have the feature of being able to adjust the drive-current.
The inductor is the same as the photo above but has a feedback winding of 15 turns.
Connect the circuit via a 220R resistor and if the LED does not illuminate, reverse the feedback winding.
The driver transistor will need a small heatsink.



BUCK CONVERTER for HIGH-POWER LED 210mA

This circuit will drive 1 high-power white LED from a 12v supply and is capable of delivering 210mA.
The driver transistor is BD 139 and the details of the inductor are shown above.
The voltage across the LED is approx 3.3v - 3.5v
The driver transistor will need a small heatsink.
The 2R2 can be increased if a lower drive-current is required.

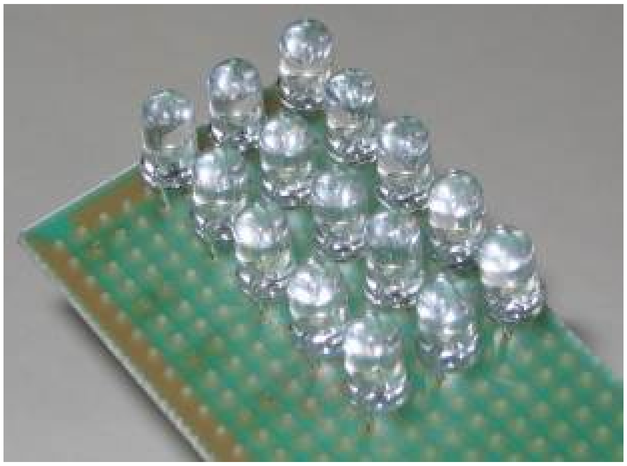


Designed 12-8-2011

BUCK CONVERTER for HIGH-POWER LED 250mA - 1watt LED

This circuit will drive 1watt white LED from a 12v supply and is capable of delivering 300mA.
The driver transistor is BC 327 and the inductor is 70 turns of 0.25mm wire wound on the core of a 10mH inductor.
See Inductor to learn how the inductor works.
The voltage across the LED is approx 3.3v - 3.5v
The 1R is used to measure the mV across it. 300mV equals 300mA LED current.
The diode MUST be high speed. A non-high-speed diode increases current 50mA!
This circuit is the best design as it does not put peaks of current though the LED. Reduce 390R slightly to increase max. current.

MAKE YOUR OWN 1-WATT LED



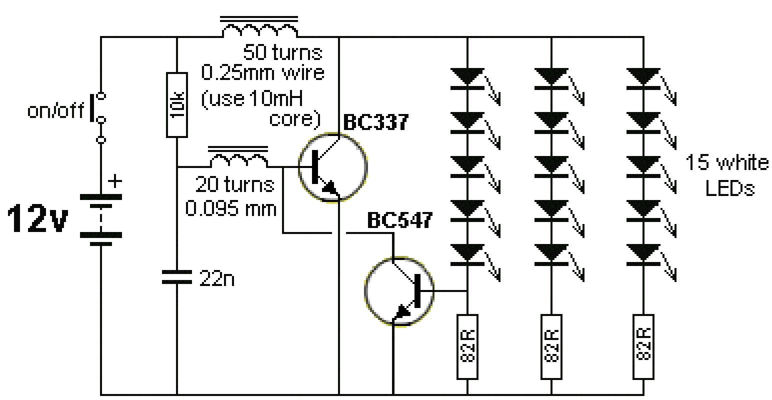
15 LEDs on Matrix board

The transformer consists of 50 turns 0.25mm wire connected to the pins. The feedback winding is 20 turns 0.095mm wire with "fly-leads."

This circuit drives 15 LEDs to produce the same brightness as a 1-watt LED. The circuit consumes 750mW but the LEDs are driven with high-frequency, high-voltage spikes, and become more-efficient and produce a brighter output that if driven by pure-DC.

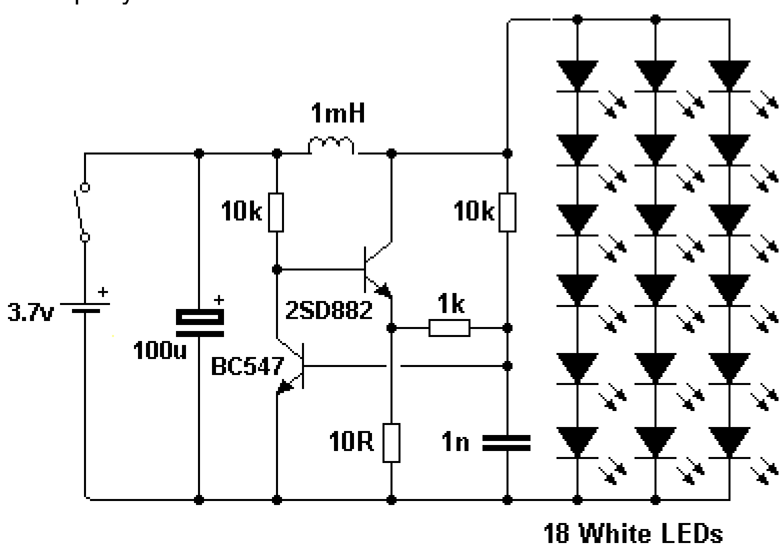
The LEDs are connected in 3 strings of 5 LEDs. Each LED has a characteristic voltage of 3.2v to 3.6v making each chain between 16v and 18v. By selecting the LEDs we have produced 3 chains of 17.5v Five LEDs (in a string) has been done to allow the circuit to be powered by a 12v battery and allow the battery to be charged while the LEDs are illuminating. If only 4 LEDs are in series, the characteristic voltage may be as low as 12.8v and they may be over-driven when the battery is charging. (Even-up the characteristic voltage across each chain by checking the total voltage across them with an 19v supply and 470R dropper resistor.) The transformer is shown above. It is wound on a 10mH choke with the original winding removed. This circuit is called a "**boost circuit**." It is not designed to drive a single 1-watt LED (a buck circuit is needed).

The LEDs in the circuit are 20,000mcd with a viewing angle of 30 degrees (many of the LED specifications use "half angle." You have to test a LED to make sure of the angle). This equates to approximately 4 lumens per LED. The 4-watt CREE LED claims 160 lumens (or 40 lumens per watt). Our design is between 50 - 60 lumens per watt and it is a much-cheaper design.

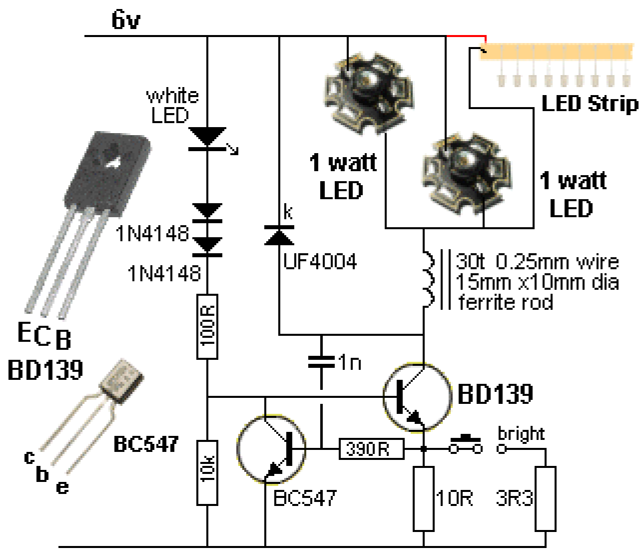


18 LEDs using a 3.7v Li-Ion CELL

This circuit drives 18 white LEDs from a 3.7v Li-Ion cell. It has been designed by Samuel Budiyanto budiyantosamuel90@gmail.com using components from an old Compact Fluorescent Lamp. No data is available on the 1mH inductor and the circuit has been provided for experimentation purposes ONLY.
It is an interesting circuit because the two transistors provide a constant brightness and the BC547 provides feedback to keep the circuit oscillating.
The 10k base resistor seems very high but the circuit has been tested for 12 hours on a 1200mA-Hr cell and the brightness remained constant.
The brightness is determined by how hard you drive the 2SD882 transistor.
It is turned on by the 10k resistor and this will deliver very little current, but since the transistor has a gain of 100 to 300, the collector current will be up to about 100mA.
Basically the circuit will over-drive the LEDs and the BC547 will limit the current to the required brightness level.
The BC547 transistor has the effect of turning OFF the 2SD at a particular instant in each cycle to reduce the time when it is turned ON. The BC547 gets its "timing" from the 10k and 1k resistors, by the fact that these resistors form a voltage divider to produce a voltage on the base. When the 2SD turns ON, a voltage is developed across the 10R that adds to this voltage but it is delayed slightly by the 1n capacitor. The 1n determines the frequency at which the circuit will oscillate. By experimenting with these 4 components you get the required brightness and this remains constant for the life of the cell.
All the LEDs are in series on each string and the brightness will depend on matching each string. By swapping some of the LEDs you will be able to adjust the brightness to make them all emit equally.



1-WATT LED - a very good designn



Circuit takes 70mA on LOW brightness and 120mA on HIGH Brightness
see MOD below

This circuit has been specially designed for a 6v rechargeable battery or 5 x 1.2v NiCad cells. **Do not use any other voltage.**
It has many features:
The pulse-operation to the two 1-watt LEDs delivers a high current for a short period of time and this improves the brightness.
The circuit can drive two 1-watt LEDs with extremely good brightness and this makes it more efficient than any other design.
The circuit is a two-transistor high-frequency oscillator and it works like this:
The BD139 is turned ON via the base, through the white LED and two signal diodes and it amplifies this current to appear though the collector-emitter circuit.
This current flows though the 1-watt LED to turn it ON and also through the 30-turn winding of the inductor. At the same time the current through the 10R creates a voltage-drop and when this voltage rises to 0.65v, the BC547 transistor starts to turn ON. This robs the base of the BD139 of "turn-on voltage" and the current through the inductor ceases to be expanding flux, but stationary flux.
The 1n capacitor was initially pushing against the voltage-rise on the base of the BC547 but it now has a reverse-effect of allowing the BC547 to turn ON.
This turns off the BD139 a little more and the current through the inductor reduces.
This creates a collapsing flux that produces a voltage across the coil in the opposite direction. This voltage passes via the 1n to turn the BC547 ON and the BD139 is fully turned OFF.
The inductor effectively becomes a miniature battery with negative on the lower LED and positive at the anode of the Ultra Fast diode. The voltage produced by the inductor flows through the UF diode and both 1-watt LEDs to give them a spike of high current. The circuit operates at approx 500kHz and this will depend on the inductance of the inductor.
The circuit has about 85% efficiency due to the absence of a current-limiting resistor, and shuts off at 4v, thus preventing deep-discharge of the rechargeable cells or 6v battery.
The clever part of the circuit is the white LED and two diodes. These form a zener reference to turn the circuit off at 4v. The 10k resistor helps too.
The circuit takes 70mA on low brightness and 120mA on HIGH brightness via the brightness-switch.
The LEDs actually get 200mA pulses of current and this produces the high brightness.

The Inductor

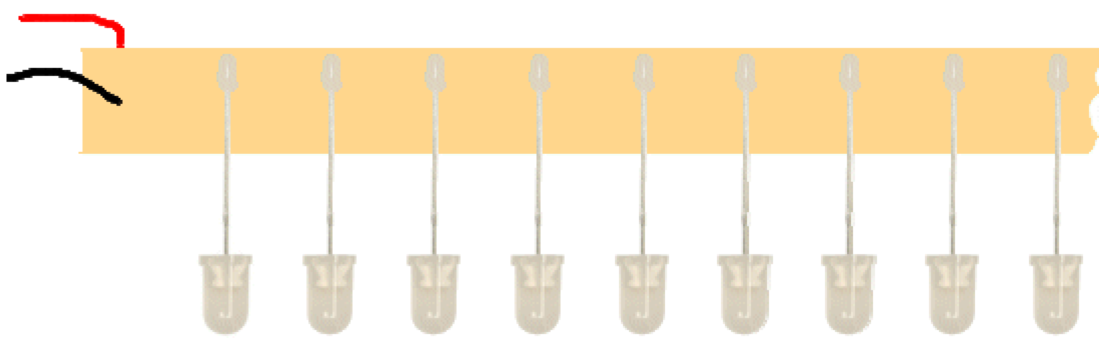
The coil or inductor is not critical. You can use a broken antenna rod from an AM radio (or a flat antenna slab) or an inductor from a computer power supply. Look for an inductor with a few turns of thick wire (at least 30) and you won't have to re-wind it.
Here are two inductors from surplus outlets:
http://www.goldmine-elec-products.com/prodinfo.asp?number=G16521B - 50 cents
http://www.allelectronics.com/make-a-store/item/CR-345/345-UH-TOROIDAL-INDUCTOR/1.html - 40cents

Here are the surplus inductors:

The cost of surplus is from 10 cents to 50 cents, but you are sure to find something from a computer power supply.
Pick an inductor that is about 6mm to 10mm diameter and 10mm to 15mm high. Larger inductor will not do any damage. They simply have more ferrite material to store the energy and will not be saturated. It is the circuit that delivers the energy to the inductor and then the inductor releases it to the LEDs via the high speed diode.

IMPROVEMENT

By using the following idea, the current reduces to 90mA and 70mA and the illumination over a workbench is much better than a single high-power LED. It is much brighter and much nicer to work under.
Connect fifteen 5mm LEDs in parallel (I used 20,000mcd LEDs) by soldering them to a double-sided strip of PC board, 10mm wide and 300mm long. Space them at about 20mm. I know you shouldn't connect LEDs in parallel, but the concept works very well in this case. If some of the LEDs have a characteristic high voltage and do not illuminate very brightly, simply replace them and use them later for another strip.
You can replace one or both the 1-watt LEDs with a LED Strip, as shown below:



No current-limit resistor. . . . why isn't the LED damaged?

Here's why the LED isn't damaged:
When the BD139 transistor turns ON, current flows through the LEDs and the inductor. This current gradually increases due to the gradual turning-on of the transistor and it is also increasing through the inductor. The inductor also has an effect of slowing-down the "in-rush" of current due to the expanding flux cutting the turns of the coil, so there is a "double-effect" on avoiding a high initial current. That's why there is little chance of damaging the LEDs.
When it reaches 65mA, it produces a voltage of .065 x 10 = 650mV across the 10R resistor, but the 1n is pushing against this increase and it may have to rise to 150mA to turn on the BC547. LEDs can withstand 4 times the normal current for very short periods of time and that's what happens in this case. The BD139 is then turned off by the voltage produced by the inductor due to the collapsing magnetic flux and a spike of high current is passed to the LEDs via the high speed diode. During each cycle, the LEDs receive two pulses of high current and this produces a very high brightness with the least amount of energy from the supply. All the components run "cold" and even the 1-watt LEDs are

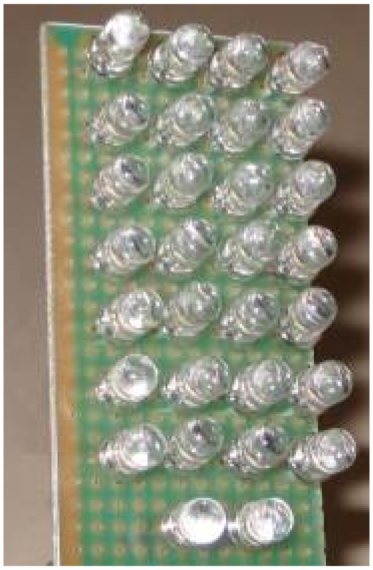
hardly warm.

Charging and Discharging

This project is designed to use all your old NiCad cells and mobile phone batteries.
It doesn't matter if you mix up sizes and type as the circuit takes a low current and shuts off when the voltage is approx 4v for a 6v pack.
If you mix up 600mA-Hr cells with 1650mA-Hr, 2,000mA-Hr and 2,400mA-Hr, the lowest capacity cell will determine the operating time.
The capacity of a cells is called "C."
Normally, a cell is charged at the 14 hour-rate.
The charging current is 10% of the capacity. For a 600mA-Hr cell, this is 60mA. In 10 hours it will be fully charged, but charging is not 100% efficient and so we allow another 2 to 4 hours.
For a 2,400mA-Hr cell, it is 240mA. If you charge them faster than 14-hr rate, they will get HOT and if they get very hot, they may leak or even explode. But this project is designed to be charged via a solar panel using 100mA to 200mA cells, so nothing will be damaged.
Ideally a battery is discharged at C/10 rate. This means the battery will last 10 hours and for a 600mA-Hr cell, this is 60mA. If you discharge it at the "C-rate," it will theoretically last 1 hour and the current will be 600mA. But at 600mA, the cells may only last 45 minutes. If you discharge is at C/5 rate, it will last 5 hours.
Our project takes 120mA so no cell will be too-stressed. A 600mA-Hr cell will last about 4-5 hours, while the other cells will last up to 24 hours. Try to keep the capacity of each cell in a "battery-pack" equal.

MODIFICATIONS FROM A READER budiyantosamuel90@gmail.com

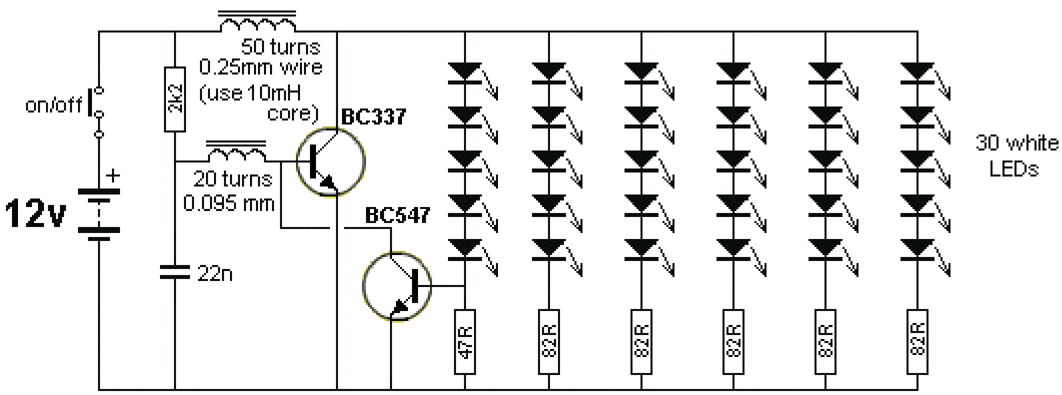
The 390R changed to 1k. The 1n changed to 470p. Replaced the UF4004 with 4 x 1N4148 in parallel.
The result is amazing, much brighter! I can't believe it.
I put 20 white LEDs in a LED strip... and it works nicely.
Much brighter than two 1 Watt LEDs.
Colin: If the length of a ferrite rod is too short, the magnetic material will saturate and it will not accept any more current and it will start to produce losses by heating-up. A toroid may work better because it will accept a higher flux density because the magnetic path does not have an air gap. (a ferrite rod is said to have an air-gap at the ends of the rod). That's why a toroid will be smaller than a rod.



30 LEDs on Matrix board

1.5 WATT LED

The circuit below can be modified to drive up to 30 white LEDs.
The effectiveness of a LED array increases when they are spread out slightly and this makes them more efficient than a single 1 watt or 2 watt LED.
The two modifications to the circuit make the BC337 work harder and this is the limit of the inductor. The current consumption is about 95mA.
The winding details for the transformer are shown above.



DRIVE 20 LEDs FROM 12v - approx 1watt circuit

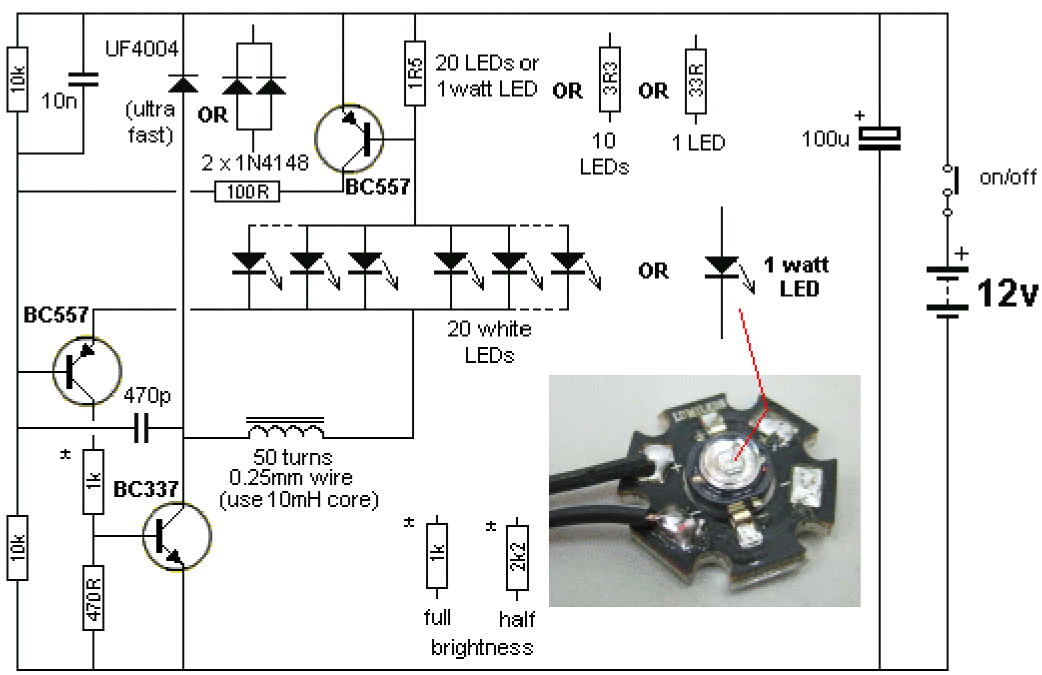
This is another circuit that drives a number of LEDs or a single 1 watt LED. It is a "**Buck Circuit**" and drives the LEDs in parallel. They should be graded so that the characteristic voltage-drop across each of them is within 0.2v of all the other LEDs. The circuit will drive any number from 1 to 20 by changing the "sensor" resistor as shown on the circuit. The current consumption is about 95mA @ 12v and lower at 18v. The circuit can be put into dim mode by increasing the drive resistor to 2k2. The UF4004 is an ultra fast 1N4004 - similar to a high-speed diode. You can use 2 x 1N4148 signal diodes.

The circuit will not drive two LEDs in series - it runs out of voltage (and current) when the voltage across the load is 7v. It oscillates at approx 200kHz. Build both the 20 LED and 1 watt LED version and compare the brightness and effectiveness.
The photo of the 1 watt LED on the left must be heatsinked to prevent the LED overheating. The photo on the circuit diagram shows the LED mounted on a heatsink and the connecting wires.

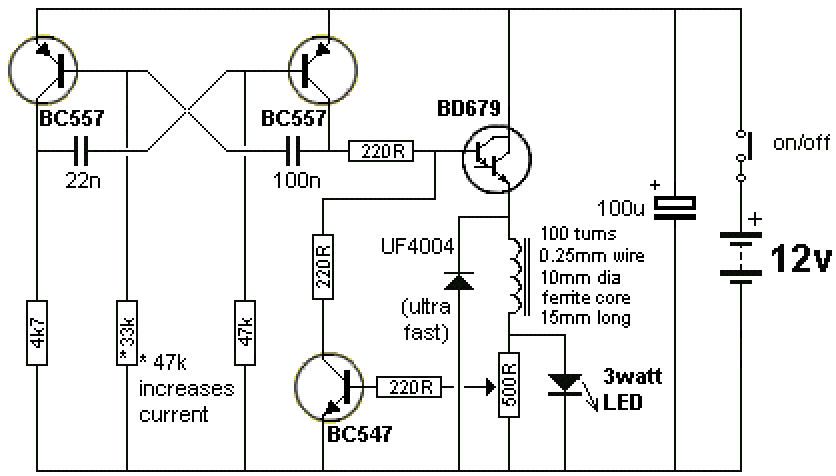
A 1-watt demo board showing the complex step-up circuitry.

This is a Boost circuit to illuminate the LED and is completely different to our design. It has been included to show the size of a 1 watt LED.

The reason for a Boost or Buck circuit to drive one or more LEDs is simple. The voltage across a LED is called a "characteristic voltage" and comes as a natural feature of the LED. We cannot alter it. To power the LED with exactly the correct amount of voltage (and current) you need a supply that is EXACTLY the same as the characteristic voltage. This is very difficult to do and so a resistor is normally added in series. But this resistor wastes a lot of energy. So, to keep the loses to a minimum, we pulse the LED with bursts of energy at a higher voltage and the LED absorbs them and produces light. With a Buck circuit, the transistor is turned on for a short period of time and illuminated the LEDs. At the same time, some of the energy is passed to the inductor so that the LEDs are not damaged. When the transistor is turned off, the energy from the inductor also gives a pulse of energy to the LEDs. When this has been delivered, the cycle starts again.

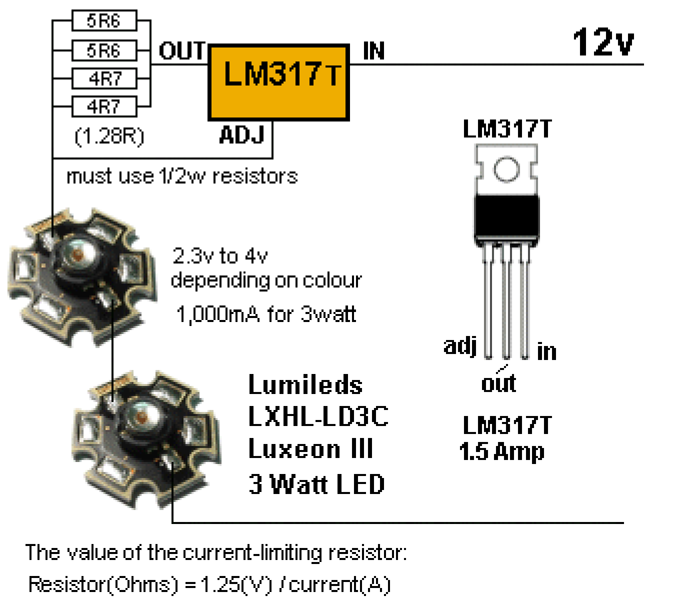


BUCK CONVERTER for 3watt LED



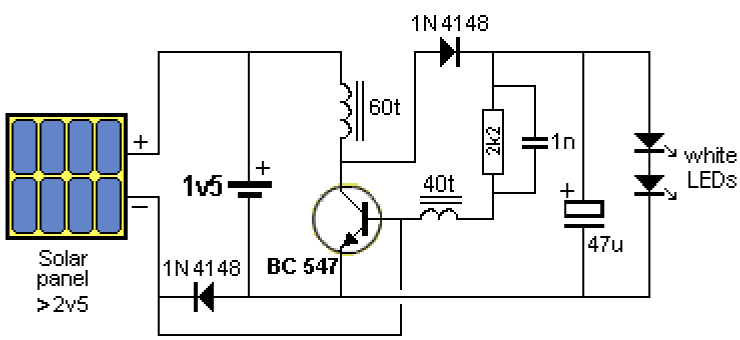
This circuit drives a 3watt LED. You have to be careful not to damage the LED when setting up the circuit. Add a 10R to the supply rail and hold it in your fingers. Make sure it does not get too hot and monitor the voltage across the resistor. Each 1v represents 100mA. The circuit will work and nothing will be damaged. If the resistor "burns your fingers" you have a short circuit.
The BC557 multivibrator has a "mark-to-space ratio" determined by the 22n and 33k, compared to the 100n and 47k, producing about 3:1 The BD679 is turned ON for about 30% of the time. This produces a very bright output, and takes about 170mA for 30% of the time. You cannot measure this current with a meter as it reads the peak value and the reading will be totally false. The only way to view the waveform is on a CRO, and calculate the current.
The 100-turn inductor allows the BD679 turn turn ON fully and "separates" the voltage on the emitter of the BC679 from the voltage on the top of the 3watt LED.
When the BD679 turns ON, the emitter rises to about 10v. But the top of the LED **NEVER** rises above 3.6v. The inductor "buffers" or "separates" these two voltages by producing a voltage across the winding equal to 6.4v and that's why the LED is not damaged.
When the transistor turns off (for 60% of the time), the magnetic flux produced by the current in the inductor collapses and produces a voltage in the opposite direction. This means the inductor now becomes a miniature battery and for a very short period of time it produces energy to illuminate the LED. The top of the inductor becomes negative and the bottom is positive. The current flows through the LED and through the Ultra High-Speed 1N4004 diode to complete the circuit. Thus the circuit takes advantage of the energy in the inductor.
A 500R pot is placed across the LED and a voltage is picked off the pot to turn on a BC547 transistor. This transistor "robs" some of the "turn-on" for the BD679 transistor to reduce the brightness of the LED.
Because the circuit is driving the LED with pulses, very high brightness is obtained with a low current. Our eyes detect peak brightness and you can compare the performance of this circuit with a DC driven LED.

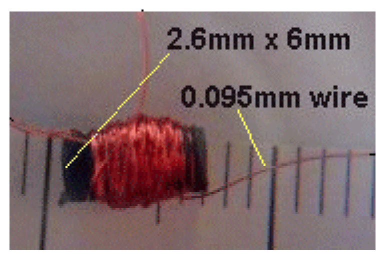
CONSTANT CURRENT DRIVES TWO 3WATT LEDs



http://www.reuk.co.uk/LM317-Current-Calculator.htm

This constant current circuit is designed to drive two 3-watt Luxeon LEDs. The LEDs require 1,000mA (1Amp) and have a characteristic voltage-drop across them of about 3.8v. Approximately 4v is dropped across the LM317T regulator and 1.25v across the current-limiting resistors, so the input voltage (supply) has to be 12.85v. A 12v battery generally delivers 12.6v.
The LM 317T 3-terminal regulator will need to be heatsinked.
This circuit is designed for the LM series of regulator as they have a voltage differential of 1.25v between "adj" and "out" terminals.





Transformer Details
core: F29 material

AUTOMATIC GARDEN LIGHT

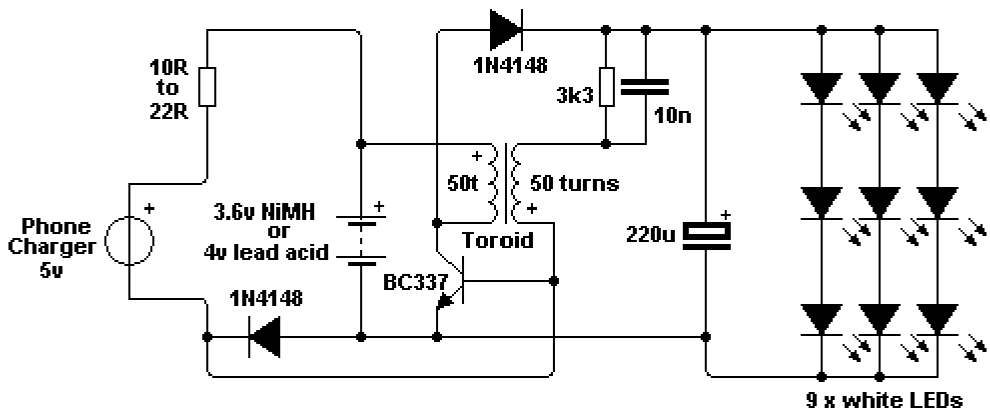
This circuit automatically turns on and illuminates the LEDs when the solar panel does not detect any light. It switches off when the solar panel produces more than 1v and charges the battery when the panel produces more than 1.5v + 0.6v = 2.1v

AUTOMATIC BATHROOM LIGHT or PASSAGE LIGHT

by Samuel Budiyanto budiyantosamuel90@gmail.com

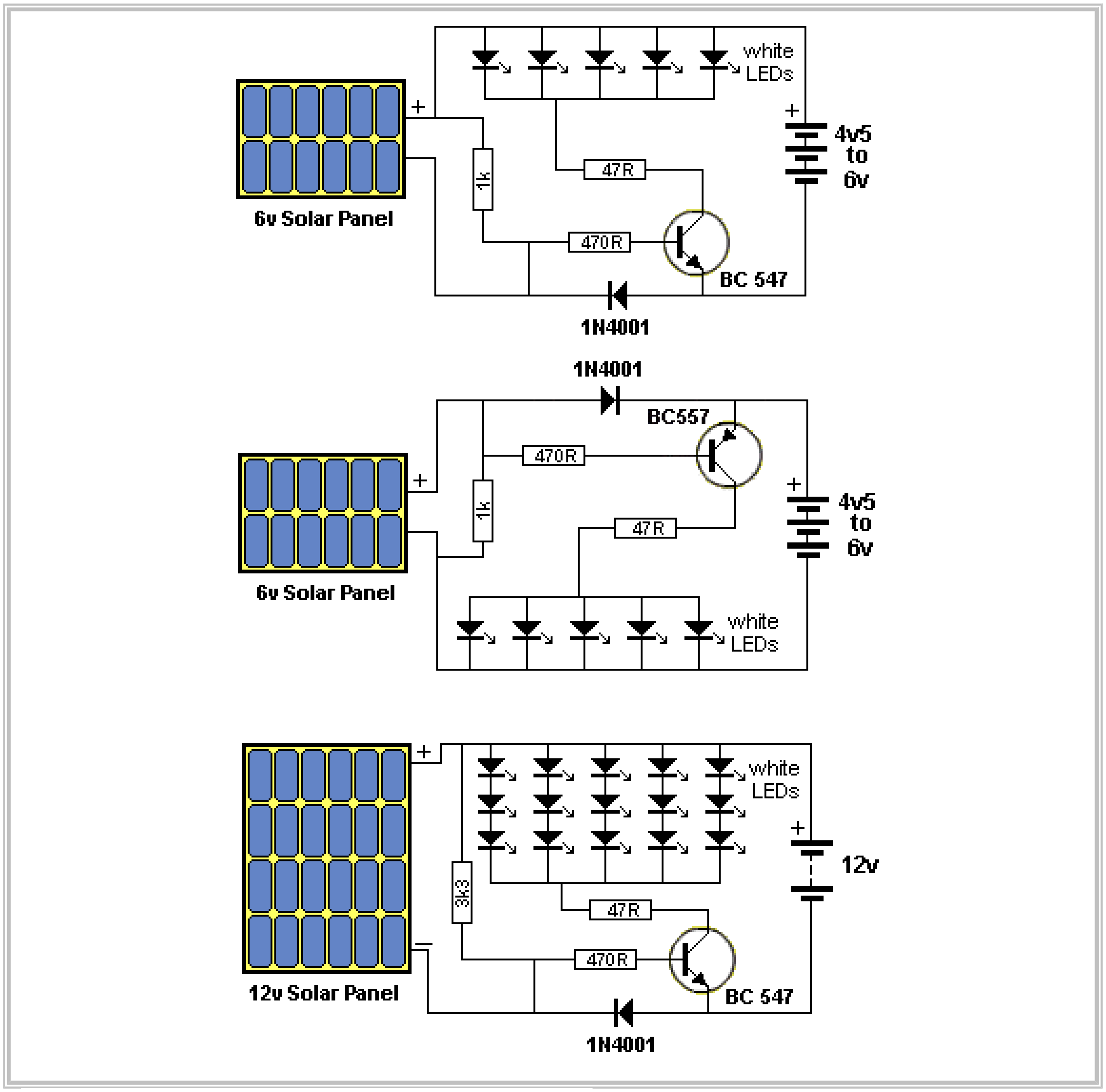
This circuit is for all those who experience black-outs and "power-outs."

It uses a 5v charger from an old mobile phone to trickle charge a 3.6v cell or 2 x lead acid cells. Use a small toroid about 40mm diameter or a 10mm ferrite rod 40mm long and 0.25mm wire. Keep the charge to 10mA to 20mA and the LEDs will come on every time the power fails. My circuit has been working for the past 7 months. If the LEDs don't illuminate with equal brightness, change them around and they will equalise.



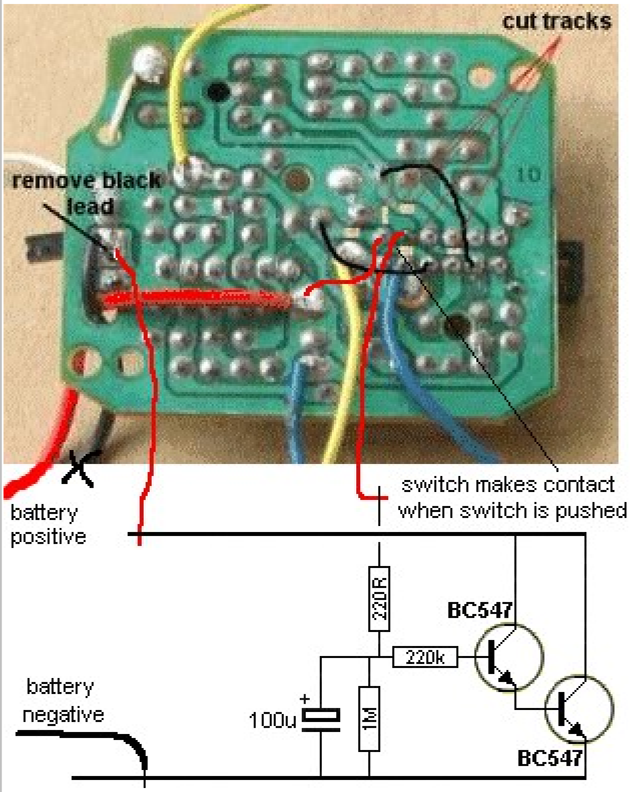
AUTOMATIC SOLAR LIGHT

This circuit automatically turns on and illuminates the LEDs when the solar panel does not detect any light. It switches off when the solar panel produces more than 0.5v above the battery voltage.
You can use any number of white LEDs. LEDS should not be connected in parallel, however they work if you selects LEDs that produce the same brightness. Any dull LEDs can be used in another circuit.
When the solar panel receives sunlight, the voltage on the base of the transistor keeps it turned OFF. When the panel receives no illumination, the 470R and 1k resistors turn the transistor ON.
You can use a 6v 0.5watt or 1 watt solar panel and the first circuit uses an NPN transistor while the second circuit uses a PNP transistor.
The output of the solar panel automatically adjusts to the voltage of the battery and as more light is detected by the panel, the current increases.
A 0.5watt panel contains 100mA cells and a 1watt panel contains 200mA cells. The battery can have any capacity from 600mAHr to 1800mAHr.
We are assuming the battery is used all night and is flat in the morning.
A 600mAHr battery will take 6-8 hours to fully charge with a 0.5watt panel and a 1800mAHr battery will take 2 days to charge with a 1 watt panel.
Each white LED requires about 20mA for good brightness and the 47R resistor will have to be adjusted to suit the battery voltage and the number of LEDs.
The third circuit uses a 12v 0.5watt or 1 watt solar panel and the circuit is much more efficient as 3 white LEDs can be connected in series for each 20mA of current.


white LEDs
4v5 to 6v
6v Solar Panel
47R
1k
470R
BC 547
1N4001
1N4001
BC557
470R
1k
47R
4v5 to 6v
6v Solar Panel
white LEDs
white LEDs
12v
3k3
47R
470R
12v Solar Panel
BC 547
1N4001

27MHz DOOR PHONE

This circuit turns a walkie talkie into a handy wireless door phone. It saves wiring and the receiver can be taken with you upstairs or outside, without loosing a call from a visitor.
A 5-Transistor walkie talkie can be used (see circuit above) and the modifications made to the transmitter and receiver are shown below:

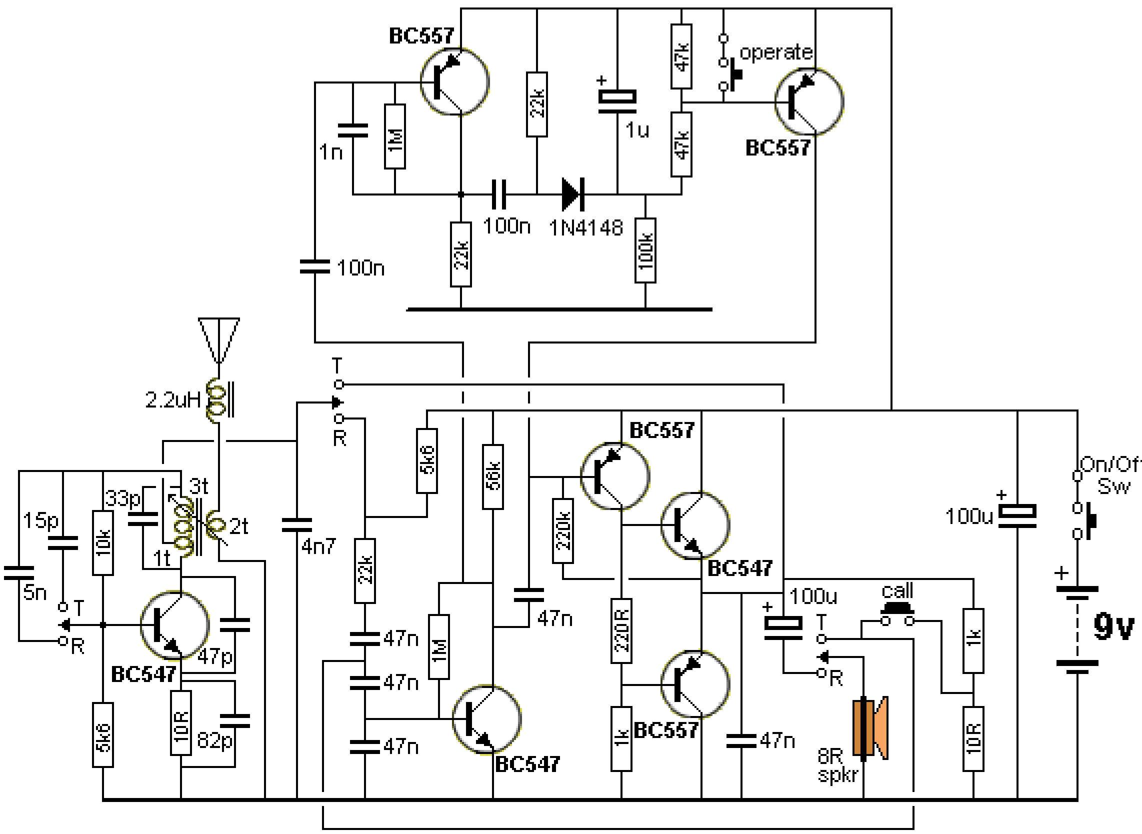


THE TRANSMITTER

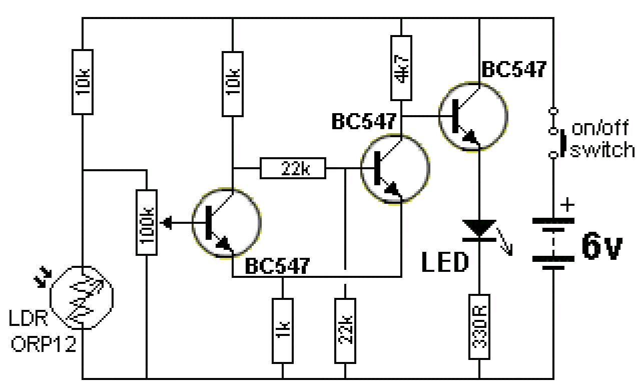
Only three sections of the transmit/ receive switch are used in the walkie talkie circuit and our modification uses the fourth section. Cut the tracks to the lands of the unused section so it can be used for our circuit.
There are a number of different printed circuit boards on the market, all using the same circuit and some will be physically different to that shown in the photo. But one of the sections of the switch will be unused.
Build the 2-transistor delay circuit and connect it to the walkie talkie board as shown. When the "push-to-talk" switch is pressed, the PC board will be activated as the delay circuit effectively connects the negative lead of the battery to the negative rail of the board for about 30 seconds.
The 100u gradually discharges via the 1M after the "press-to-talk" switch is released and the two transistors turn off and the current drops to less than 1 micro-amp - that's why the power switch can be left on. .
The transmitter walkie talkie is placed at the front door and the power switch is turned on. To call, push the "push-to-talk" switch and the "CALL" button at the same time for about 5 seconds. The circuit will activate and when the "push-to-talk" switch is released, the circuit will produce background noise for about 30 seconds and you will hear when call is answered.
The "push-to-talk" switch is then used to talk to the other end and this will activate the circuit for a further 30 seconds. If the walkie talkie does not have a "CALL" switch, 3 components can be added to provide feedback, as shown in the circuit below, to produce a tone.

THE RECEIVER

The receiver circuit needs modification and a 2-transistor circuit is added. This circuit detects the tone and activates the 3-transistor direct-coupled amplifier so that the speaker produces a tone.
The receiver circuit is switched on and the 2-transistor circuit we connect to the PC board effectively turns on the 3-transistor amplifier so that the quiescent current drops from 10mA to about 2-3mA. It also mutes the speaker as the amplifier is not activated. The circuit remains on all the time so it will be able to detect a "CALL." When a tone is picked up by the first two transistors in the walkie talkie, it is passed to the first transistor in our "add-on" section and this transistor produces a signal with sufficient amplitude to remove the charge on the 1u electrolytic. This switches off the second transistor and this allows the 3-transistor amplifier to pass the tone to the speaker. The operator then slides a switch called "OPERATE" to ON (down) and this turns on the 3-transistor amplifier. Pressing the "push-to-talk" switch (labelled T/R) allows a conversation with the person at the door. Slide the "OPERATE" switch up when finished.



The receiver walkie talkie with the 2-transistor "add-on"



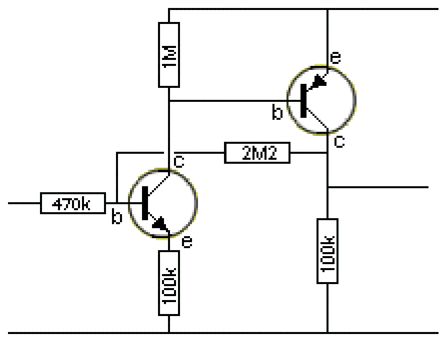
SCHMITT TRIGGER

A Schmitt Trigger is any circuit that has a fast change-over from one state to the other. In our case we have used 2 transistors to produce this effect and the third is an emitter-follower buffer.
The circuit will drive a LED or relay and the purpose is to turn the LED ON quickly at a particular level of illumination and OFF at a higher level. The gap between ON and OFF is called the HYSTERESIS GAP.

SCHMITT TRIGGER-2

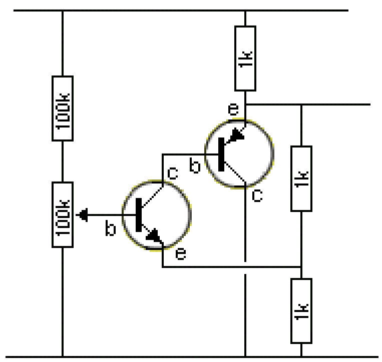
The following circuit is a Schmitt Trigger made with NPN and PNP

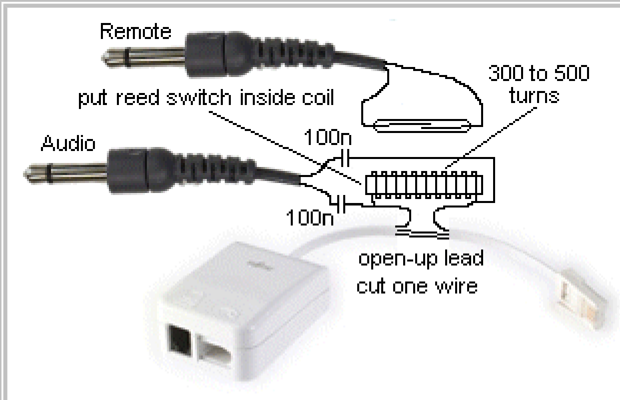
transistors:



SCHMITT TRIGGER-3

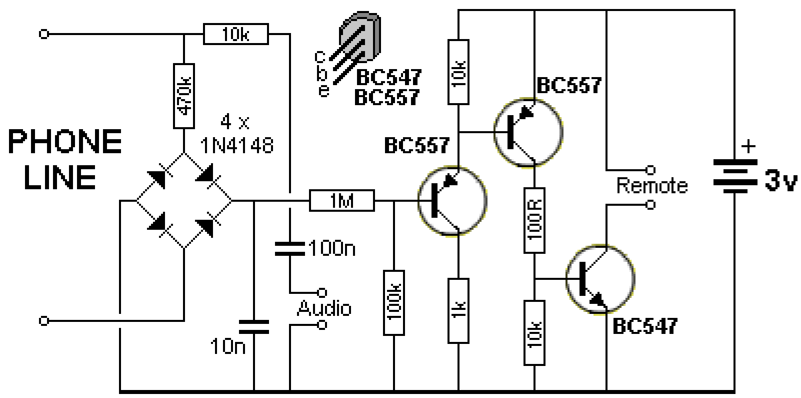
The following circuit is another Schmitt Trigger made with NPN and PNP transistors. The 100k "stop resistor" on the 100k prevents the circuit turning ON when the pot is near the supply rail.





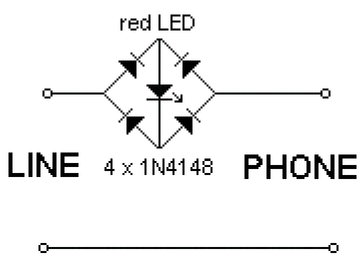
PHONE TAPE - 1

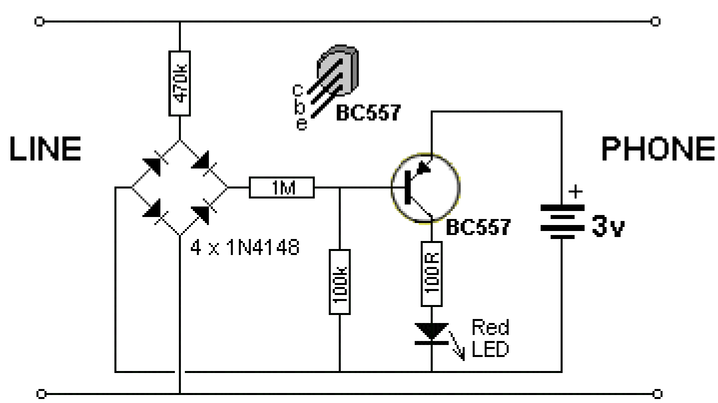
This simple circuit will allow you to tape-record a conversation from a phone line.
It must be placed between the plug on the wall and the phone.
The easiest way is to cut an extension lead. Wind 300-500 turns of 0.095mm wire on a plastic straw and place the reed switch inside. Start with 300 turns and see if the reed switch activates, Keep adding turns until the switch is reliable.
Fit two 100n capacitors to the ends of the winding for the audio. Plug the Audio into "Mic" on tape recorder. Plug the remote into "remote" on the tape recorder and push "record." The tape recorder will turn on when the phone is lifted and record the conversation.



PHONE TAPE - 2

The circuit is turned off when the phone line is 45v as the voltage divider made up of the 470k, 1M and 100k puts 3.5v on the base of the first BC557 transistor. If you are not able to cut the lead to the phone, the circuit above will record a conversation from an extension lead. The remote plug must be wired around the correct way for the motor to operate.





PHONE ALERT

Two circuits are available to show when a phone is being used. The first circuit must be placed between the socket on the wall and the phone - such as cutting into the lead and insert the bridge and diode.

But if you cannot cut the lead to the phone, you will have to add an extension cord and place the second circuit at the end of the line. You can also connect a phone at the end if needed.

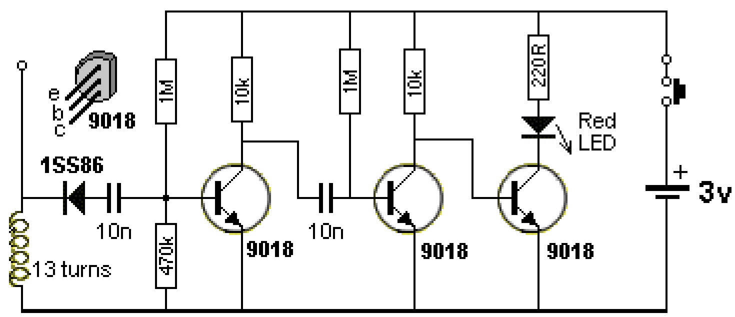
PHONE ALERT-2 (for mobile phone)

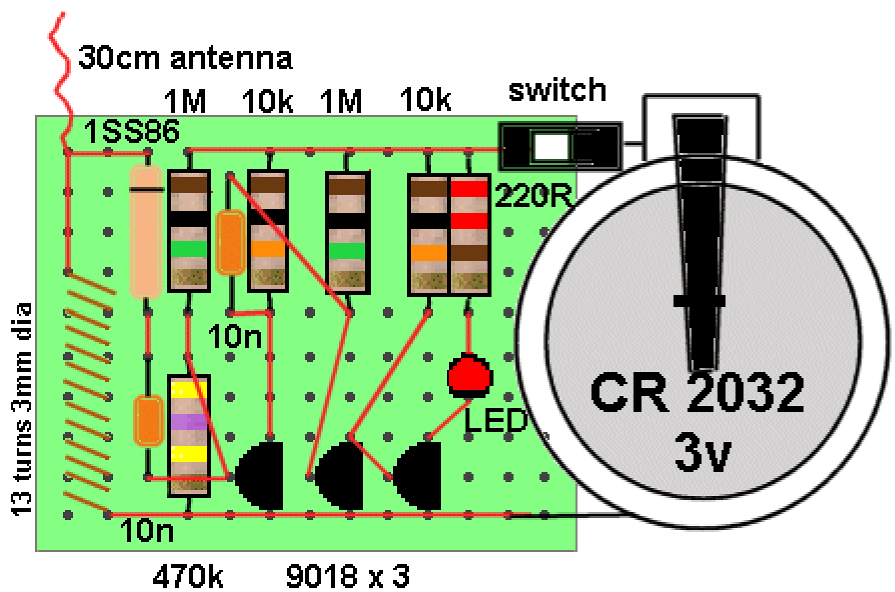
This circuit detects the RF when the phone is communicating with the tower during the hand-shaking prior to it ringing.

The 1SS86 is a Silicon Schottky Barrier Diode for UHF circuits and is 100 times more sensitive than a 1N4148 signal diode. Many of the "clone" 1SS86 diodes (fake or really another type of diode) sold on eBay NOT NOT WORK. The characteristics of the 1SSS86 are really amazing.

This is an ideal circuit to test different diodes.

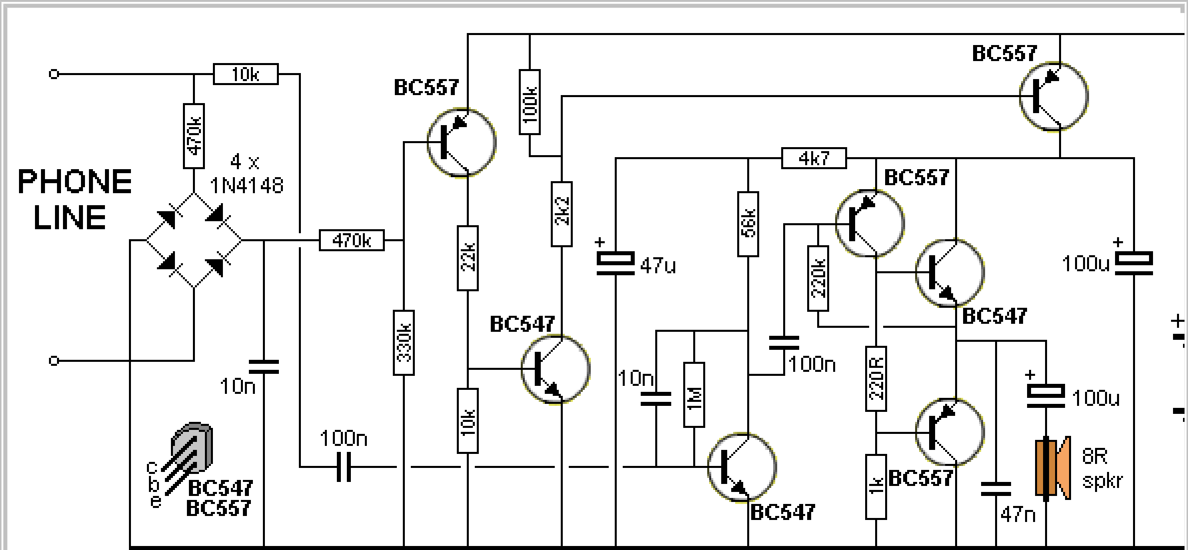
The first transistor is biased ON and the signal (waveform) developed across the coil takes the cathode end of the diode NEGATIVE for part of the cycle and this puts a slightly lower voltage on the left lead of the 10n capacitor. The right-lead follows and a slightly lower voltage is applied to the base of the transistor. The transistor turns OFF slightly and this effect is passed to the other two transistors to flash the LED.
With 1N4148, the phone must be 10cm from the project. With a 1SS86 it can be one metre away. The circuit takes about 1mA.





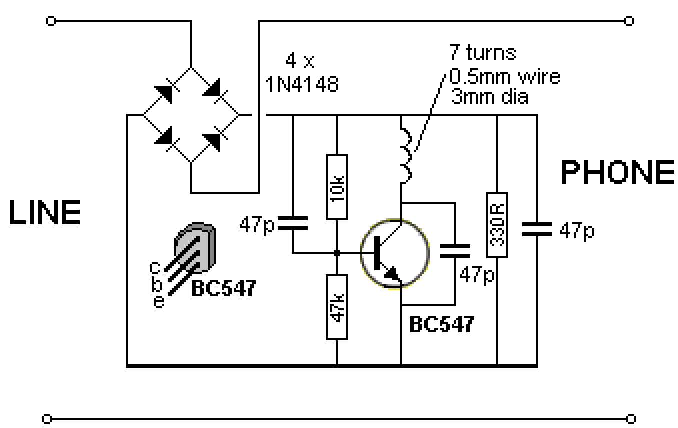
A kit is available from Talking Electronics for $3.00 plus $4.50 postage. The project is built on Matrix Board as shown in the drawing above. **Phone Alert kit**

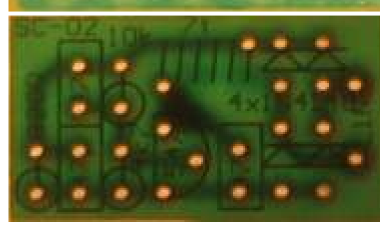
-



THE LISTENER

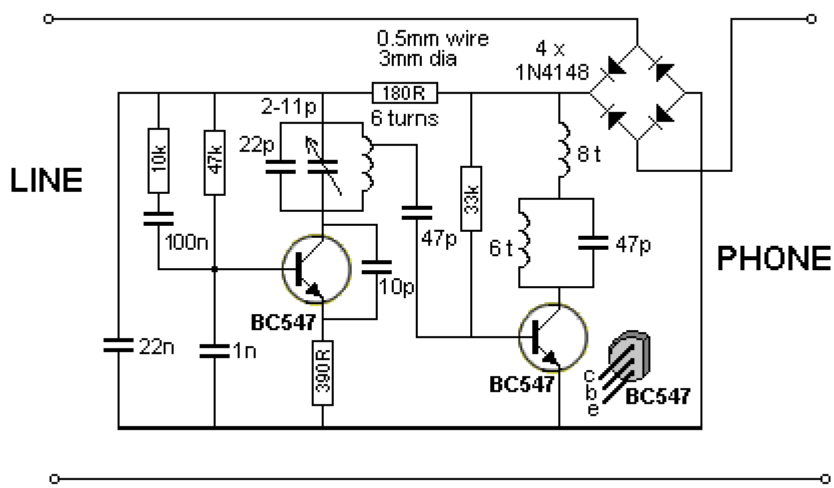
This circuit consists of a 4-transistor amplifier and a 3-transistor "switch" that detects when the phone line is in use, and turns on the amplifier. The voltage divider at the front end produces about 11v on the base of the first BC557 and this keeps the transistor off. Switch the unit off when removed from the phone line.





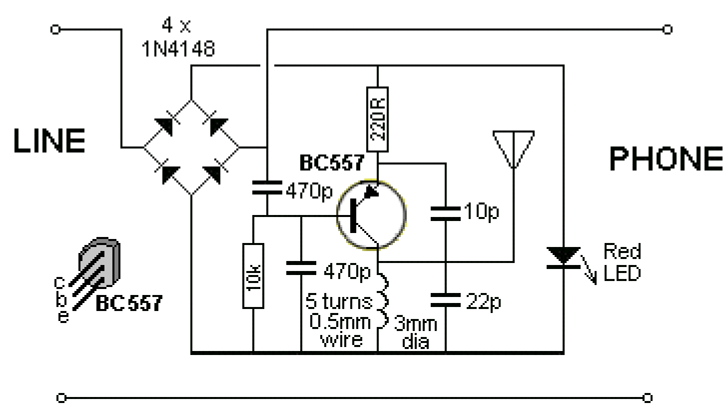
PHONE TRANSMITTER - 1 **see also Phone Bug circuit in: 101-200 circuits**

The circuit will transmit a phone conversation to an FM radio on the 88-108MHz band. It uses energy from the phone line to transmit about 100metres. It uses the phone wire as the antenna and is activated when the phone is picked up. The components are mounted on a small PC board and the lower photo clearly shows the track-work.



PHONE TRANSMITTER - 2 **see also Phone Bug (101-200 circuits)**
The circuit will transmit a phone conversation to an FM radio on the 88-108MHz band. It uses energy from the phone line to transmit about 200metres. It uses the phone wire as the antenna and is activated when the phone is picked up.

PHONE TRANSMITTER - 3 **see also Phone Bug (101-200 circuits)**
This circuit has poor features but you can try it and see how it performs. It uses a PNP transistor and requires a separate antenna. It also has a supply of less than 1.9v, via the red LED. It would be better to put 2 LEDs in series to get a higher voltage. It is activated when the phone is picked up.



PHONE TRANSMITTER - 4

see also Phone Bug (101-200 circuits)

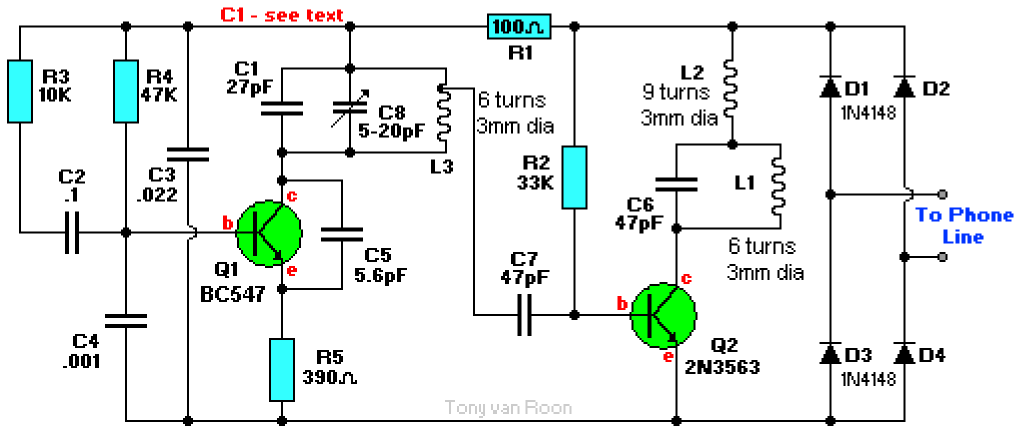
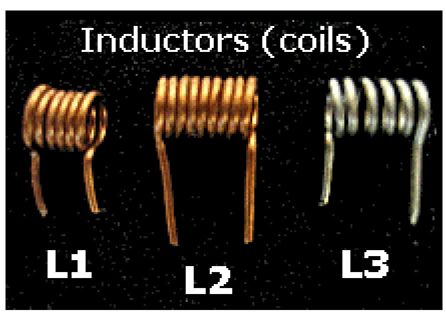


Fig.1-Here's the FM Telephone Transmitter schematic diagram. The circuit connects in series with a phone line, "steals" power from it, and transmit both sides of the conversation to an FM radio tuned between 80 - 108MHz

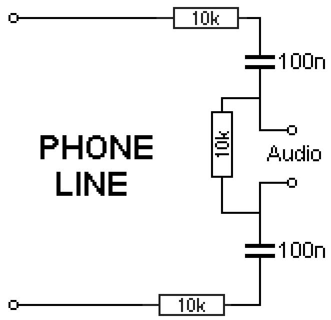


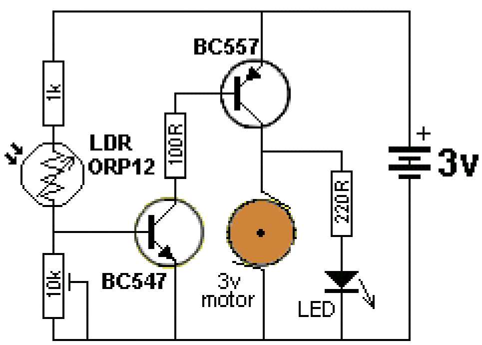
The circuit was originally designed by me and presented in Poptronics magazine. It will transmit a phone conversation to an FM radio on the 88-108MHz band. It uses energy from the phone line to transmit about 200metres and uses the phone wire as the antenna. It is activated when the phone is picked up. The 22p air trimmer is shown as well as the 3 coils. Q2 is a buffer transistor between the oscillator and phone line and will provide a higher output than the previous circuits.

MUSIC ON HOLD

This simple circuit delivers audio to the phone line from the "audio-out" of a tape recorder or radio.

Adjust the volume control of the radio to produce a suitable level of audio.
Use 400v capacitors to be on the safe-side.





ROBOT-1

A simple robot can be made with 2 motors and two light-detecting circuits, (identical to the circuit above). The robot is attracted to light and when the light dependent resistor sees light, its resistance decreases. This turns on the BC547 and also the BC557. The shaft of the motor has a rubber foot that contacts the ground and moves the robot. The two pots adjust the sensitivity of the LDRs. This kit is available from Velleman as kit number MK127.

SWITCH DEBOUNCER and PULSE PRODUCER

Thus is one of the simplest and cleverest circuits ever produced (by Ron: http://www.zen22142.zen.co.uk/ronj/tg1.html
Ron says: It produces a **complete pulse** every time the button is pressed. When the button is pressed, the output goes low for 3uS and produces a pulse to activate the clock-line of a chip. Our circuit produced 100% reliability and the cap takes 0.1sec to discharge.
The circuit does not have any filtering to prevent switch noise as it relying on the fact that a single pulse is produced in 3uS and the circuit assumes no switch noise can be produced in that time-interval.

100 more transistor circuits: 101-200 Circuits

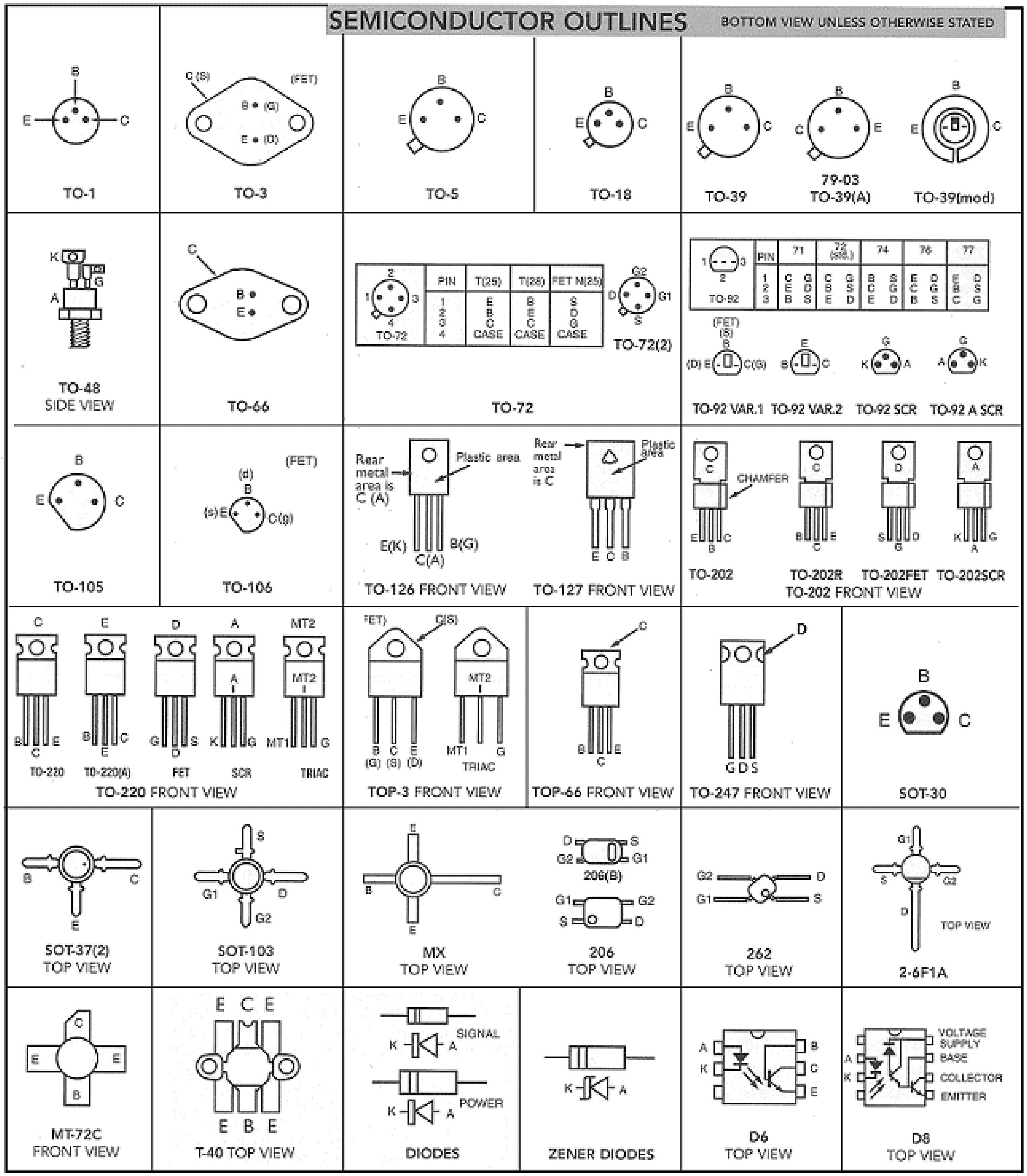
Go to Talking Electronics website: HERE for "new page" format click: HERE

BIPOLAR TRANSISTORS

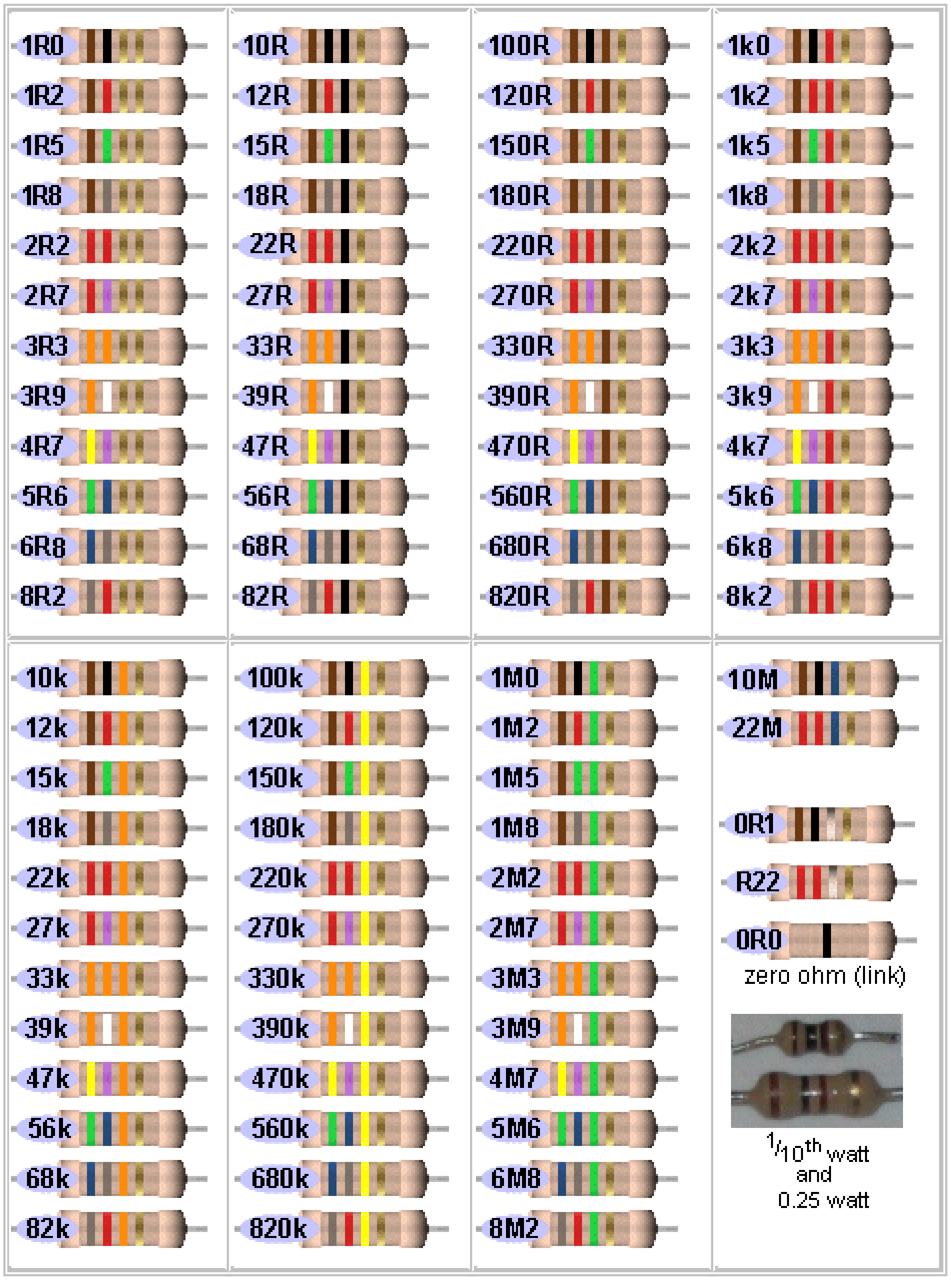
Some small signal transistors may have a TO-92 case and a "PN" prefix. The electrical specifications are the same, only the case is changed.

Type	CASE		V_{CE}	V_{CB}	I_C	V_{CEC}	@I_C	h_{FE}	@I_C	FT	@I_C	P_{TOT}	USE	COMPARABL TYPES
		Polarity	mA				mA		mA	MHz	mA	mW		
BC107	TO-18	NS	45	50	100	0.2	10	110-450	2	300	10	300	G.P S.S. amp.	BC207, BC147, BC
BC108	TO-18	NS	20	30	100	0.2	10	110-800	2	300	10	300	G.P S.S. amp.	BC208, BC148, BC
BC109	TO-18	NS	20	30	100	0.25	10	200-800	2	300	10	300	Low noise S.S. amp	BC209, BC149, BC
BC109C	TO-18	NS	20	30	100	0.25	10	420-800	2	300	10	300	Low noise high gain	BC209C BC149C
BC177	TO-18	PS	45	50	100	0.3	10	75-260	2	150	10	300	G.P S.S. amp.	BC157, BC307, BC
BC178	TO-18	PS	25	30	100	0.3	10	75-500	2	150	10	300	G.P. S.S. amp.	BC158, BC308, BC
BC179	TO-18	PS	20	25	100	0.3	10	125-500	2	150	10	300	G.P S.S. amp.	BC159, BC309, BC
BC327	TO-92VAR1	PS	45	50	500	0.7	500	100-600	100	100	10	625	Output	2N3638
BC328	TO-92VAR1	PS	25	30	500	0.7	500	100-600	100	100	10	625	Output	BC327
BC337	TO-92VAR1	NS	45	50	500	0.7	500	1 00-600	100	100	10	625	Output	2N3642
BC338	TO-92VAR1	NS	25	30	500	0.7	500	100-600	100	100	10	625	Output	BC337
BC546	TO-92VAR1	NS	65	80	100	0.6	100	110-450	2	300	10	500	G.P S.S. amp.	
BC547	TO-92VAR1	NS	45	50	100	0.6	100	110-800	2	300	10	500	G.P S.S. amp.	BC107, BC207, BC
BC548	TO-92VAR1	NS	30	30		0.6	100	110-800	2	300	10	500	G.P. S.S. amp.	BC108, BC208, BC1
BC549	TO-92VAR1	NS	30	30	100	0.6	100	200-800	2	300	10	500	Low noise S.S. amp.	BC109, BC209, BC
BC549C	TO-92VAR1	NS	30	30	100	0.6	100	420-800	2	300	10	500	Low noise high gain	BC109C, BC149C
BC556	TO-92VAR1	PS	65	80	100	0.65	100	75-475	2	200	10	500	G.P. S.S. amp.	
BC557	TO-92VAR1	PS	45	50	100	0.65	100	75-800	2	200	10	500	G.P. S.S. amp.	BC157
BC558	TO-92VAR1	PS	30	30	100	0.65	100	75-800	2	200	10	500	G.P. S.S. amp.	BC158
BC559	TO-92VAR1	PS	30	30	100	0.65	100	125-800	2	200	10	500	G.P. S.S. amp.	BC159
BC639	TO-92(74)	NS	80	100	1A	0.5	500	40-250	150	130		1W	Audio O/P	MU9610, TT801
BC640	TO-92(74)	PS	80	100	1A	0.5	500	40-250	150	50		1W	Audio O/P	MU9660, TT800
BD139	TO-126	NS	80	10	1.5A	0.5	500	40-250	150	250	50	8W	G.P. O/P	40409
BD140	TO-126	PS	80	10	1.5A	0.5	500	40-250	150	75	50	8W	G.P. O/P	40410
BD262	TO-126	PS	60	60	4A	2.5	1.5A	750	1.5A	7	1.5A	36W	High gain Darl. O/P	BD266
BD263	TO-126	NS	60	80	4A	2.5	1.5A	750	1.5A	7	1.5A	36W	High gain Darl. O/P	BD267
BD266A	TO-220	PS	80	80	8A	2	3A	750	3A	7		60W	High gain Darl. O/P	
BD267A	TO-220	NS	80	10	8A	2	3A	750	3A	7		60W	High gain Darl. O/P	
BD681	TO-126	NS	100	10	4A	2.5	1,5A	750	1.5A	1		40W	Darlington O/P	BD263
BD682	TO-126	PS	100	100	4A	2.5	1.5A	750	1.5A	1		40W	Darlington O/P	BD262
BF173	TO-72(28)	NS	25	40	25			40-100	7	550	5	230	T.V. I.F. amp.	
BF199	TO-92VAR2	NS	25	40	25			37	7	550		500	H.F. amp.	BF180
BF463	TO-202	PS	250	25	500			40-180	30	20		2W	H.V. med. power.	
BF469	TO-126	NS	250	25	50			50	25	60	10	1.8W	G.P high-V. amp.	
BF470	TO-126	PS	250	25	50			50	25	60	10	1.8W	G.P. high-V. amp.	
BFR90	SOT-37(2)	NS	15	20	25			25-250	14	5GHz	14	180	Wideband amp..	
BFR91	SOT-37(2)	NS	12	15	35	0.3	30	25-250	30	5GHz	30	180	Wideband amp.	
BFY90	TO-72(25)	NS	15	30	25			25-125	2	1GHz	2	200	Wideband amp.	
BUX80	TO-3	NS	400	80	10A	1.5	5A	30	1.2A	8		100W	Defl'n, high current	
MJ802	TO-3	NS	90	10	30A	0.8	7.5A	25-100	7.5A	2	1A	200W	High power output	
MJ2955	TO-3	PS	60	70	15A	1.1	4A	20-70	4A	2.5	500	115W	G.P. power	
MJ4502	TO-3	PS	90	10	30A	0.8	7.5A	25-100	7.5A	2	1A	200W	High power output	
MJ10012	TO-3	NS	400	60	10A	2	6A	100-2K	6A			175W	Power Darlington	
MJ15003	TO-3	NS	140	14	20A	1	5A	25-150	5A	2	500	250W	High power output	
MJ15004	TO-3	PS	140	140	20A	1	5A	25-150	5A	2	500	250W	High power output	
MJE340	TO-126	NS	300		500	0.75	100	30-240	50			20W	G.P. H.V. power	

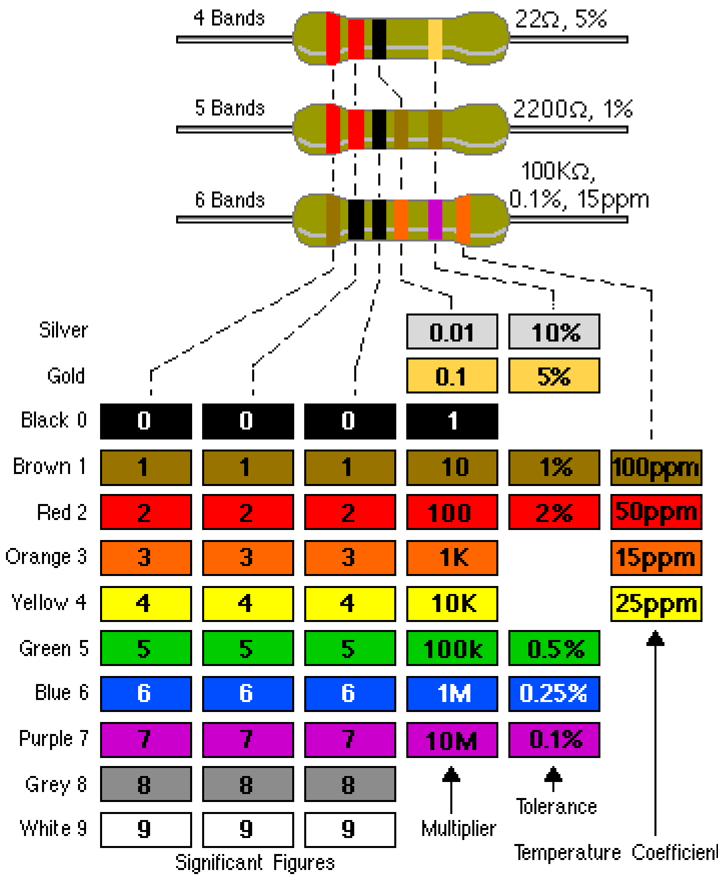
Type	CASE		V_{CE}	V_{CB}	I_C	V_{CEC}	@I_C	h_{FE}	@I_C	FT	@I_C	P_{TOT}	USE	COMPARABL TYPES
		Polarity	mA				mA		mA	MHz	mA	mW		
MJE350T	TO-126	PS	300		500	0.77	100	30-240	50			20W	G.P. H.V. power	
MJE2955	TO-220	PS	60	70	10A	1.1	4A	20-100	4A	2	500	75W	G.P. power	TIP 2955
MJE3055T	TO-220	NS	60	70	10A	1.1	4A	20-100	4A	2	500	75W	G.P. power	TIP 3055
MPSA14	TO-92(72)	NS	30	30	500	1.5	100	20000	100	125	10	625	G.R Darlington	
MPSA65	TO-92(72)	PS	30	30	500	1.5	100	20000	100	100	10	625	G.P. Darlington	
MRF629	TO-39A	NS	16	36	400			20-200	100			5W	UHF power	
MRF660	TO-220A	NS	16	36	2.4A			20-160	250			25W	UHF power	
PN100	TO-92(72)	NS	35	60	500	0.5	100	60-240	150	350	50	600	G.P. amp/switch	PN2222, 2N3643
PN2907	TO-92(72)	PS	40	60	600	0.4	150	100-300	150	200	50	625	High S. switch	
PN200	TO-92(72)	PS	35	60	500	0.5	1 50	50-400	150	200	50	600	G.P. amp/switch	2N3638, BC214
TIP31B	TOP-66	NS	80	80	3A	1.2	3A	25	1A	3	500	40W	Power output	
TIP32B	TOP-66	PS	80	80	3A	1.2	3A	25	1A	3	500	40W	Power output	
TIP142	TOP-3	NS	100	100	10A	2	5A	>1000	5A			125W	Audio output	TIP140, TIP141
TIP147	TOP-3	PS	100	100	10A	2	5A	>1000	5A			125W	Audio output	TIP145, TIP146
TIP2955	TOP-3	PS	70	100	15A	1.1	4A	20	4A	3	500	90W	Power output	MJE2955
TIP3055	TOP-3	NS	70	100	15A	1.1	4A	20	4A	3	500	90W	Power output	MJE3055
2N2222A	TO-18	NS	40	75	800	1.6	500	00-300	150	300	20	500	High S. switch	
2N3019	TO-39	NS	80	140	1A	0.5	500	50-100	500	100	50	800	H.F. amp	
2N3053	TO-39	NS	40	60	700	1.4	150	50-250	150	100	50	2.86W	G.R switch	BD137
2N3054	TO-66	NS	60	90	4A	0.1	200	25-100	500	0.8	200	25W	Audio output	TIP31B
2N3055	TO-3	NS	60	70	15A	1.1	4A	20-70	4A	2.5	500	115W	G.P. power	BDY20
2N3563	TO-106	NS	15	30	50			0-200	8	600	8	200	RF-IF amp	BF173
2N3564	TO-106	NS	15	30	100	0.3	20	20-500	15	400	15	200	RF-IF amp	BF167
2N3565	TO-106	NS	25	30	50	0.35	1	150-600	1	400	1	200	Low level amp	BC108, BC208
2N3566	TO-105	NS	30	40	200	1	100	50-600	10	40	30	300	G.R amp & switch	BC183
2N3567	TO-105	NS	40	80	500	0.25	150	40-120	150	60	50	300	G.P. amp & switch	BC337
2N3568	TO-105	NS	60	80	500	0.25	150	40-120	150	60	50	300	G.P. amp & switch	
2N3569	TO-105	NS	40	80	500	0.25	150	00-300	150	60	50	300	G.P. amp & switch	
2N3638A	TO-105	PS	25	25	500	0.25	50	100	50	150	50	300	G.P. amp & switch	BC328
2N3641	TO-105	NS	30	60	500	0.22	150	40-120		250	50	350	G.P. amp & switch	BC337
2N3642	TO-105	NS	45	60	500	0.22	150	40-120		250	50	350	G.R amp & switch	BC337
2N3643	TO-105	NS	30	60	500	0.22	150	100-300	150	250	50	350	G.P. amp & switch	BC337
2N3644	TO-105	PS	45	45	500	1	300	100-300	150	200	20	300	G.P. amp & switch	BC327
2N3645	TO-105	PS	60	60	500	1	300	100-300	150	200	20	300	G.P. amp & switch	
2N3771	TO-3	NS	40	50	30A	2	15A	15-60	15A	0.2	1A	150W	Power output	
2N3866	TO-39	NS	30	55	400			0-200	50	500	50	1W	VHF amp	
2N3904	TO-92(72)	NS	40	60	200	0.2	10	00-300	10	300	10	310	Low level amp	BC167A, BF194
2N3905	TO-92(72)	PS	40	40	200	0.4	50	50-200	10	200	20	310	G.P. amp & switch	
2N3948	TO-39	NS	20	36	400			15	50	700	50	1W	VHF amp	
2N4030	TO-39	PS	60	60	1A	0.5	500	25	500	260	100	800	G.P. amp & switch	
2N4250	TO-106	PS	40	40	100	0.25	10	50-700	0.1	50		200	Low level amp	BC559
2N4258	TO-106	PS	12	12	50	0.5	50	30-120	10	700	10	200	Saturated switch	
2N4427	TO-39	NS	20	40	400	0.4	100	10-200	100	500	50	1W	VHF/UHF driver	2N3866
2N5401	TO-92(72)	PS	150	160	6000	0.5	50	60-250	10	100	10	625	H.V. switch	MPSL51
2N6557	TO-202	NS	250	250	500			>40	50	45		2W	H.V. med power	
2SC710	TO-92/76	NS	25	30	30			90		100		200	G.P, RF amp	BFS18
2SC1306	TOP-66	NS	65	65	3A			0-200	500	300		12W	H.F. output	2SC2166
2SC1307	TOP-66	NS	70	70	8A			0-150	2A	150		25W	H.F. output	2SC1969
2SC1674	TO-92(74)	NS	20	30	20	0.3	10	40-180	1	600	1	250	VHP amp	
2SC1969	TOP-66	NS	30	60	6A			0-180	10	150		20W	H.F output	2SC1307
2SC2166	TOP-66	NS	75	75	4A			5-180	100					
2SC2694	T-40	NS	17	35	20A			0-180	1A	800		140W	VHF output	MRF247
2SC3355	TO-92(74)	NS	12	20	100			0-300	20	6.5GHz	20	600	UHFSS	MRF573
2SC3358	MX	NS	12	20	100			0-300	20	7GHz	20	250	UHFSS	MRF573



All the resistor colours:



1R0
1R2
1R5
1R8
2R2
2R7
3R3
3R9
4R7
5R6
6R8
8R2
10R
12R
15R
18R
22R
27R
33R
39R
47R
56R
68R
82R
100R
120R
150R
180R
220R
270R
330R
390R
470R
560R
680R
820R
1k0
1k2
1k5
1k8
2k2
2k7
3k3
3k9
4k7
5k6
6k8
8k2
10k
12k
15k
18k
22k
27k
33k
39k
47k
56k
68k
82k
100k
120k
150k
180k
220k
270k
330k
390k
470k
560k
680k
820k
1M0
1M2
1M5
1M8
2M2
2M7
3M3
3M9
4M7
5M6
6M8
8M2
10M
22M
0R1
R22
0R0
zero ohm (link)
1/10th watt
and
0.25 watt



Resistor Color Code System

See [101-200 Circuits] for resistors in parallel and series and capacitors in parallel and series. You can make ANY VALUE by simply connecting resistors in parallel or series. And the same with capacitors.

Live Traffic Stats

The Transistor Amplifier

Home

Save P1 as:
.doc (700kB .pdf (600kB)

Save P2 as:
.doc (1.6MB) .pdf (1.2MB)

See: 1- 100 Transistor Circuits
101 - 200 Transistor Circuits

P1 P2 P3 test

The Transistor Amplifier is available as a .pdf but this file is not updated as fast as the web page.
New items are added on a daily basis as we get a lot of requests from readers to help design a circuit and explain how a circuit works.
We have not opted for covering transistor circuit design as found in most text books because there are already many available on the web for free download.
We have decided to cover this topic in a completely different way, with a circuit to cover each explanation.
This way you will pick up all the pointers that the text books miss.
It's only after you start designing a circuit that you find out how little you have been supplied via conventional teaching and that's why our approach is so important.
If you look at some magazines you will find faults and poor descriptions in almost every one of their circuits.
No only is the designer poorly informed but the technical editor of the magazine is unaware of the mistakes and the readers do not reply with corrections. It's total ignorance ALL AROUND.
The Transistor Amplifier article will help you understand some of the faults and how to avoid them.
It's pointless learning about "LOAD LINES" etc and producing equations for all sorts of results when most transistors have gain-values that can be 200% more or 80% less than the chosen value.
The gain of a transistor falls 90% as the current increases and you have absolutely no idea what value to use until you build the circuit. By that time you have already solved your problem!
Secondly, it's pointless learning about equations until you have looked at the hundreds of different transistor circuits so you know what circuit to use.

TOPICS:

THE DIFFERENTIAL AMPLIFIER
or
LONG TAILED PAIR

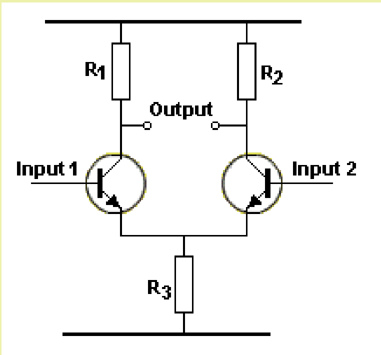


Fig 71ad

The **DIFFERENTIAL AMPLIFIER** is also called the "**Difference Amplifier"** or **long-tailed pair** (LTP), or **emitter-coupled pair,** because it amplifies the **difference** between the voltages on **Input 1** and **Input 2**. It is called a Long Tailed Pair because the emitter resistor has a high value. The circuit has the advantage of ONLY amplifying the signals on the Inputs. Any noise on the power rail is not detected on the output as both transistors will see this fluctuation and both outputs will either rise or fall and thus the output **will not change**.
Since the **Long Tailed Pair** does not pick up noise from the supply, it is ideal as a pre-amplifier as shown in the 60 watt amplifier in **Fig 71ae**:

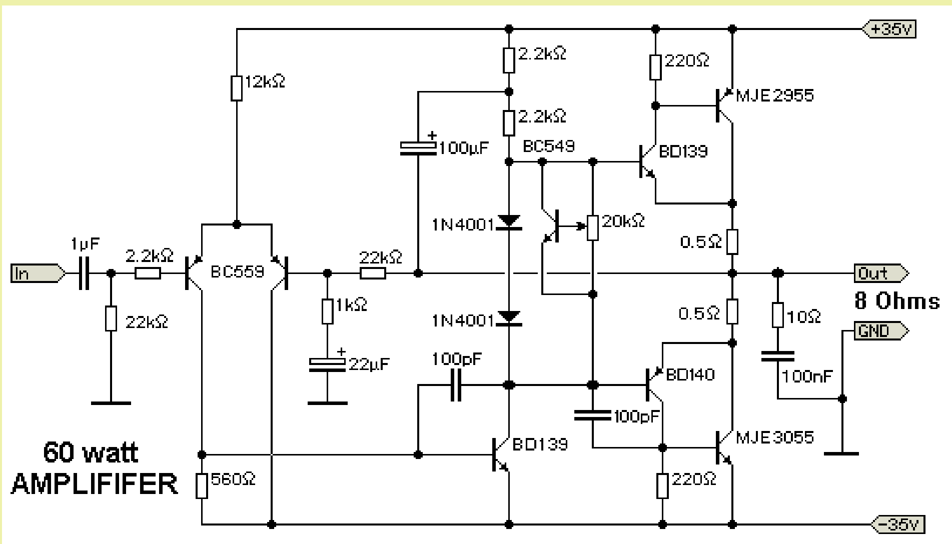


Fig 71ae

THE CONSTANT-CURRENT CIRCUIT

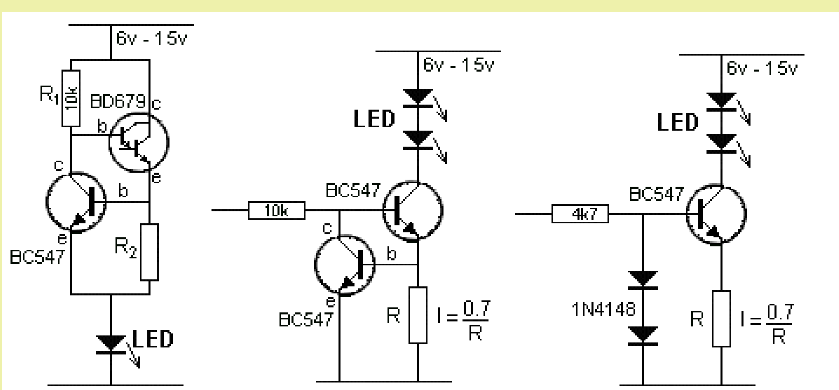


Fig 71a Constant-Current Circuits

The three circuits above provide a constant current through the LED (or LEDs) when the supply rises to 15v and higher. The second and third circuits can be turned on and off via the input line.

The first circuit in **Fig 71b** is a constant-current arrangement, providing a fixed current to the LEDs, no matter the supply voltage.
This is done by turning on the top transistor via the 2k2 resistor. It keeps turning on until the voltage-drop across resistor **R** is 0.65v. At this point the

lower transistor starts to turn on and current flows through the collector-emitter terminals and it "robs" the top transistor of current from the 2k2 resistor. The top transistor cannot turn on any more and the current flowing though R is the same as the current flowing through the LEDs and does not increase.

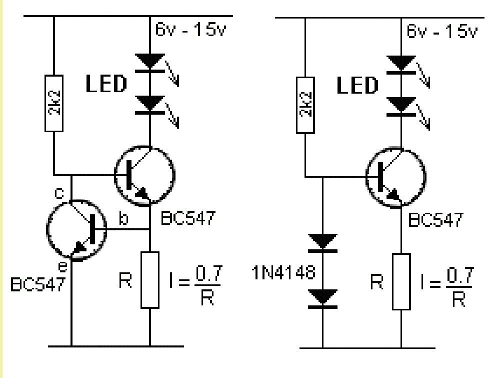


Fig 71b Constant-Current Circuit

The second diagram in **Fig 71b** is also a constant-current circuit with the base fixed at:
0.7v + 0.7v = 1.4v via the two diodes.
The transistor is turned on via the 2k2 resistor and a voltage is developed across resistor **R**. When this voltage is 0.7v, the emitter is 0.7v above the 0v rail and the base is 1.4v. If the transistor turns on more, the emitter will be 0.8v above the 0v rail and this will only give 0.6v between base and emitter. The transistor would not be turned on with this voltage-drop, so the transistor cannot be turned on any more than 0.65v across the resistor **R**.

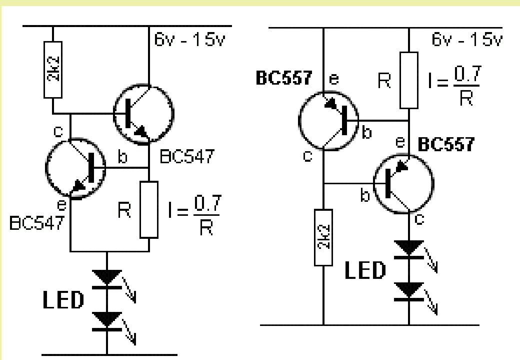


Fig 71ba Constant-Current Circuit

Fig 71ba shows two more constant current circuits "sourcing" the LEDs. The 7 constant current circuits give you the choice of either sourcing or sinking the LED current.

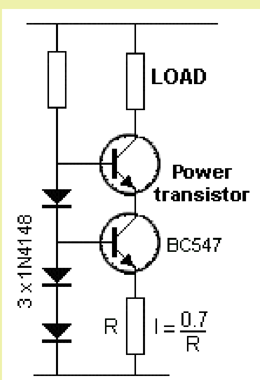


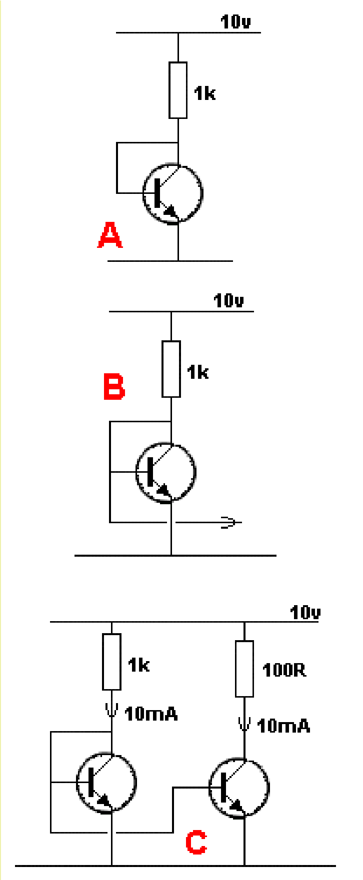
Fig 71bab Constant-Current Circuit for high voltage supply

If the supply voltage is high, the transistor controlling the current (BC547) will get hot and alter the current-flow.
Fig 71bab uses a POWER TRANSISTOR to dissipate the losses and the current-controlling transistor remains cold.

When the circuit turns ON, the current through R is zero and the voltage on the base of the BC547 turns it on fully. The voltage between collector and emitter is about 0.2v and this means the emitter of the power transistor is below the base of the BC547. The base of the power transistor is 0.7v above the base of the BC547 and the power transistor also turns on fully. Current increases through R and when the voltage across R reaches 0.7v, The BC547 starts to turn OFF. The collector voltage rises and this starts to turn OFF the power transistor. This is how the current through the LOAD is limited by the value of R.

THE CURRENT MIRROR CIRCUIT

This is not a constant current circuit. It is a **CURRENT SOURCE** circuit. A **constant current** circuit means the current will not change if the supply voltage is increased or decreased. This circuit simply supplies a DC signal (in the form of a voltage) to another circuit so that the current in the original circuit is available in the second circuit and this is called a **current mirror** arrangement.
We start with diagram **A**.
The transistor is turned on because the base is connected to the collector. The collector can only rise to about 0.7v because it is connected to the base so that most of the supply-voltage appears across the load. This means the current through the load is known.
It can be determined by Ohm's Law: I =V/R.
Here's how the circuit works: When the circuit is turned ON,

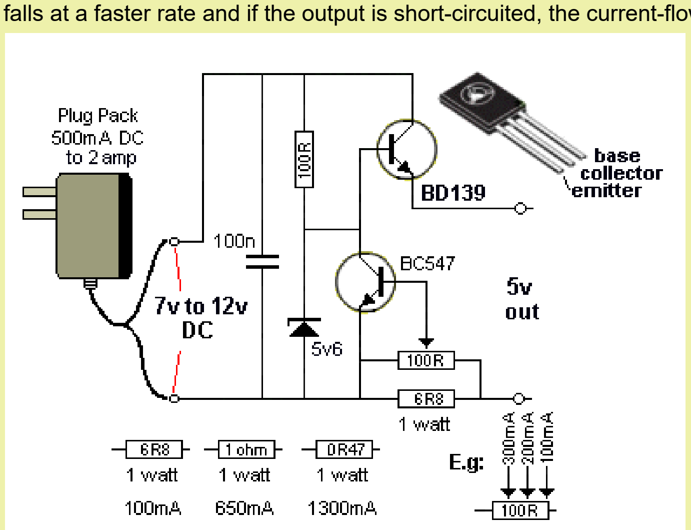


current flows through the resistor and through the base-emitter junction. This turns the transistor ON very hard and the current through the collector-emitter circuit increases. This reduces the voltage on the collector and as it decreases, the voltage on the base decreases and the transistor starts to turn OFF. In the end, the transistor is turned on to allow 10mA to flow through the collector-emitter junction due to the 10v supply and 1k resistor.
Suppose we instantly change the 1k for 100 ohms.
The transistor is only lightly turned ON and current though the collector-emitter is only 10mA. But the 100R will deliver 100mA and the extra current will flow into the base and turn the transistor ON harder. This will increase the current thorough the collector-emitter junction and rob the base of the extra current, however the current into the base will be higher than before because the transistor has to be turned on more to allow about 100mA to flow through the collector-emitter junction.
If we take a lead from the base of the transistor, as shown in fig **B** we can connect it to the base of an identical transistor and the second transistor will allow the same current to flow though the collector-emitter junction.
The result is circuit **C**. The current through the 100R resistor will be 10mA (normally it would be 100mA). The second transistor is only lightly turned on and allows 10mA to flow.

Fig 71bac Current Mirror Circuit

ADJUSTABLE CURRENT POWER SUPPLY

A reader requested a circuit for an **Adjustable-Current 5v Power Supply**.
In other words he wanted a power supply with **CURRENT LIMITING**.
This type of power supply is very handy so you can test an unknown circuit and prevent it being damaged.
For this design we will make the current adjustable from 100mA to 1 amp.
This circuit can be added to any power supply with an output of more than 7v. Our circuit requires at least two volts "head-room" for the voltage across the regulating transistor (the transistor that delivers the voltage and current) and about 0.5v for the current-detecting resistor.
The maximum current is set by the 100R pot and
This circuit delivers 5v when no current is flowing and the voltage gradually reduces. When the set value of current as selected by the 100R pot is reached the output voltage will have dropped by 0.6v. This is the voltage developed across the current-sensing resistor and this voltage is detected by the BC547 to to start to reduce the output voltage. As soon as the maximum current is reached, the voltage falls at a faster rate and if the output is short-circuited, the current-flow will be as set by the pot.



The output voltage of this power supply can be increased by changing the voltage of the zener diode. The voltage of the plug pack must be at least 3v above the output voltage to allow the regulator transistor and current-detector resistor to function.

CONSTANT CURRENT

As soon as the load reaches the point where it takes the full current, the circuit turns into a **CONSTANT CURRENT** power supply.

ADJUSTABLE CURRENT POWER SUPPLY

VOLTAGE REGULATOR

Before we go to the **2-transistor Voltage Regulator**, we will explain how a voltage regulator works.
The basis of all voltage regulators is a diode.
A diode has a voltage characteristic. When a voltage is placed across its terminals, and the voltage starts at zero, no current flows through the diode until the voltage reaches 0.65v. As soon as it reaches 0.65v, current flows and as you increase the voltage, more current flows but the voltage across the diode remains at 0.65v. If the voltage is increased further, the current increases enormously and the diode will be destroyed.
This characteristic does not apply to a resistor. The voltage across a resistor will increase when the supply voltage increases and thus a resistor cannot be used as a Voltage Regulator.
We have selected 0.65v for this discussion as this is the characteristic voltage-drop for a normal silicon diode.
However germanium diodes and Schottky diodes have different characteristic voltage drops. On top of this, special diodes can be produced with higher voltages. These are called **ZENER DIODES**. They all have the same characteristic. As soon as the specified voltage appears across the terminals of the diode, current starts to flow and if the voltage is increased too much, the diode will be damaged.
To prevent this, a resistor must be placed in series with the diode.
This is the basis of all voltage regulators.

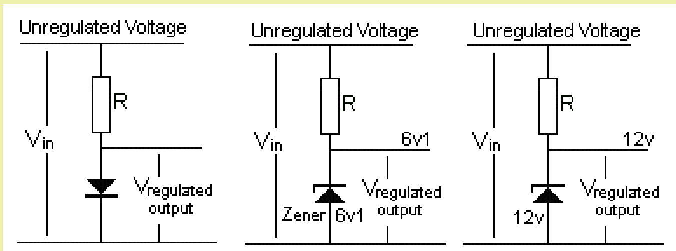


Fig 71be The Unregulated Voltage is regulated by the diode (zener)

In **Fig 71be**, the supply voltage is called the **UNREGULATED VOLTAGE** and it is connected to resistor R and a diode. The voltage at the top of the diode is called the **REGULATED VOLTAGE**. The diode produces a fixed 0.65v and the zener produces a fixed 6v1 or 12v.
This circuit is called a **SHUNT REGULATOR** because the regulator is shunted (placed across) the load. [A Shunt is a load - generally a low-value resistor - placed across a component in a circuit to take a high current to either protect the other components or to test the circuit under high-current conditions.]
That's exactly what the diode or zener diode does.
It takes ALL THE CURRENT from the unregulated supply and and feeds it to the 0v rail. During this condition the circuit is 100% wasteful. All the wattage is being lost in heating resistor R and heating the diode.
The circuit is providing a fixed voltage at the top of the zener.
When a load is added to the circuit, it takes (or draws) current and this current comes from the current flowing though the zener.
The load-current can increase to a point where it takes nearly all the current from the zener.
If it takes more current than the zener, two things happen. Current stops flowing though the zener and the voltage on the top of the zener drops to a lower value. This is the point where the zener has **dropped out of regulation** and the circuit is no longer regulating.
In other words: A current is flowing into the regulator circuit and it is being divided into two paths: The zener path and the load path. The load path cannot be more than 95% or the regulator will drop out of regulation (the output voltage goes below the zener voltage).
Here's how the diode (or the zener) works: The zener is just like a bucket with a large hole in the side. As you fill the bucket, the water (the voltage) rises until it reaches the hole. It then flows out the hole (through the zener) and does not rise any further. When you draw current from the circuit it is the same as a tap at the bottom of the bucket and the water flows out the tap and not the hole. The pressure out the tap is the voltage of the zener.
The only disadvantage of this circuit is the voltage across the zener changes a small amount when the current through it changes.
The **SHUNT REGULATOR** is limited to small currents due to the fact that the load is taking the current from the zener.
The current can be increased by adding a buffer transistor to produce a **BUFFERED SHUNT REGULATOR** as shown in **Fig 71bf.** This circuit actually becomes a PASS TRANSISTOR arrangement.

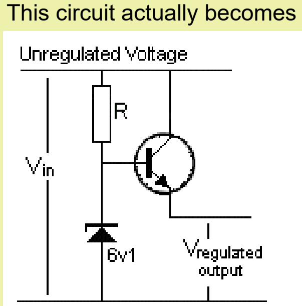
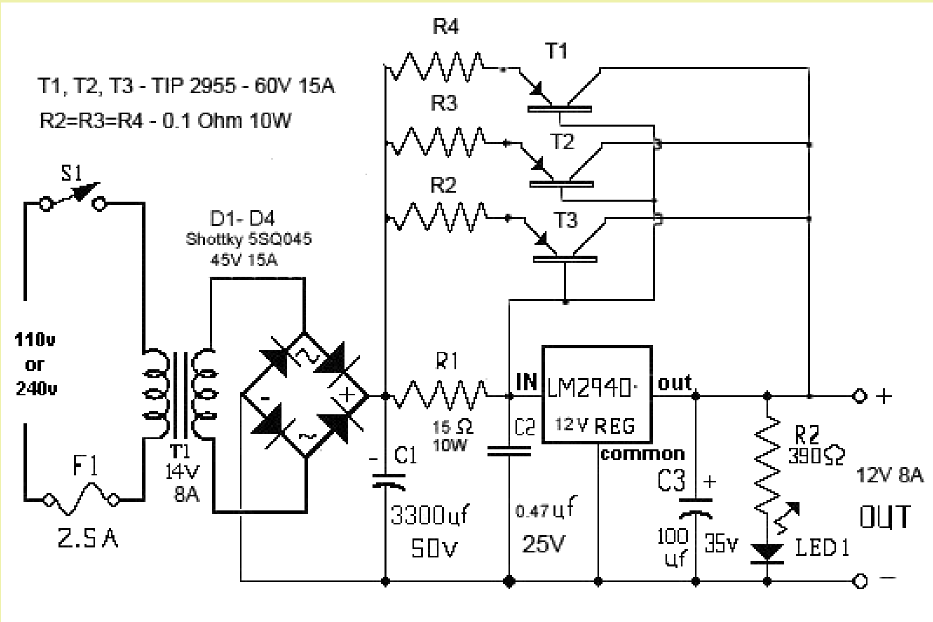


Fig 71bf Buffered Shunt Regulator

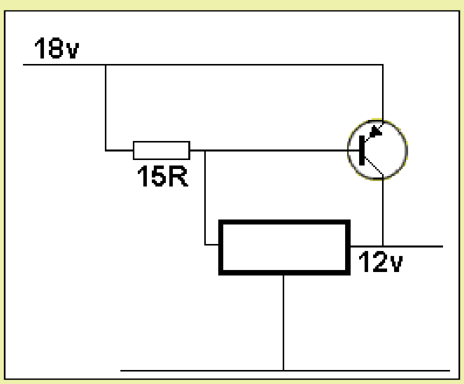
called a PASS TRANSISTOR Regulator
with the transistor in an emitter-follower configuration

The transistor operates as an **amplifier** and if the DC gain of the transistor is 100, the output current of a Buffered Shunt Regulator can be 100 times more than a Shunt regulator.
See more circuits on the **Zener Regulator** and the **Transistor Shunt Regulator** and **Pass Transistor Regulator** in 101-200 Transistor Circuits. A very clever circuit to reduce ripple is called the **Electronic Filter**.

PASS TRANSISTOR



The 3 PNP transistors in the Power Supply circuit above are called PASS TRANSISTORS, because they pass or CONDUCT the current. They pass the current from the bridge to the output.
These transistors are AMPLIFIERS - CURRENT AMPLIFIERS - as they amplify the current entering the base and deliver a higher current through the emitter-collector terminals.
To see how these transistors work, we will simplify the circuit:



Only 3 components are involved in the explanation, the transistor, the base resistor and the rectangle containing the voltage regulator IC.
The 3 emitter resistors are only needed to make sure each power transistor delivers the same current. It is called CURRENT SHARING.
The IN voltage is about 18v and the voltage OUT is fixed at 12v by the 3-terminal regulator.
The regulator produces the 12v OUT. The transistor does not have any control over the output voltage.
At the moment there is NO LOAD. The transistor is not turned on AT ALL and the output voltage is produced by the regulator. The regulator takes about 10mA to provide this condition.
Now put a LOAD on the output.
This load creates a voltage drop across the 15R and as soon as it is more than 0.6v, the transistor starts to turn ON.
As the load increase (the resistance of the load decreases) by say adding more globes, the current increases and the voltage-drop across R increases and this turns the transistor ON more.
The 3-terminal regulator (in the rectangle) delivers almost no current to the load during any of these conditions (only about 50mA !!). It is the transistor that delivers all the current.
The current PASSES through the transistor and that's why it is called a PASS TRANSISTOR.
The purpose of the 15R resistor is SOLELY to allow the transistor(s) to turn ON.

As the load takes more current, the transistor will be "asked" for this current, but it does not deliver.
So, the regulator delivers the extra current and this current flows through the emitter-base junction.
The 15R is added so that some of the current flows through the resistor.
The extra current requested by the regulator flows through the emitter-base junction of the PNP transistor and turns it ON more. This allows the transistor(s) to pass the current from the bridge to the output. The current taken by the 3-terminal regulator mainly flows through the emitter-base junction.

I don't know why the 15R is rated at 10 watts. The voltage across this resistor cannot rise to more than 1v and this means the resistor can only pass 1/15 amp = 60mA !!
Obviously the circuit has never been tested.

0000000000000000000000000000000

The whole concept of a regulator (removing the ripple while maintaining the required voltage) revolves around the voltage-drop across a diode and in **Fig 71bb**, the diode is replaced with the voltage-drop across the base-emitter junction of a transistor. This voltage-drop is fairly constant when a small current flows and this is the basis of the **Two Transistor Regulator:**

TWO TRANSISTOR REGULATOR

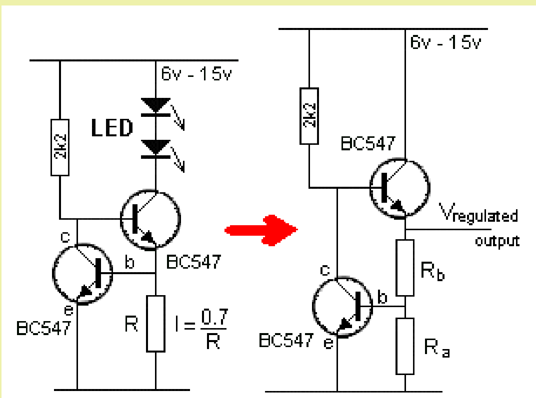


Fig 71bb

If we take the Constant-Current Circuit shown in **Fig 71b** above, and split resistor **R** into **R**a and **R**b, we produce an identical circuit with a completely different name. It is called a **TWO TRANSISTOR REGULATOR**.
The circuit will produce a smooth voltage on the output, even though the rail voltage fluctuates AND even if the current required by the output increases and decreases.
That's why it is called a REGULATOR CIRCUIT.
The current through Ra and Rb is "wasted current" so it does not have to be more than 1mA - enough to turn on the lower NPN transistor.
Ra and Rb form a voltage divider and when the join of the two resistor reaches 0.7v, the lower transistor turns ON.

The lower transistor forms a voltage-divider with the 2k2 to pull the top BC547 transistor DOWN so the voltage on the output is kept at the "design voltage" (the top transistor is an emitter follower). If the device connected to the output requires more current, the top transistor will not be able to provide it and the output voltage will drop. This will reduce the voltage on the base of the lower transistor and it will turn OFF slightly.
The voltage on the base of the top transistor will rise and since this transistor is an emitter-follower, the emitter will rise too and increase the output voltage to the original "design value."
Regulation is also maintained if the supply decreases (or increases).
If the supply decreases, the voltage on the base of the top transistor will fall and the output voltage will also fall.
The voltage on the base of the lower transistor will also fall and it will turn off slightly.
This will increase the voltage on the base of the top transistor and Vregulated will rise to the design value. Both the supply and the load can change at the same time and the circuit will compensate.
All we have to do is re-draw the circuit as a standard 2-Transistor Regulator as shown in **Fig 71bc** and you have covered the principle of its operation.

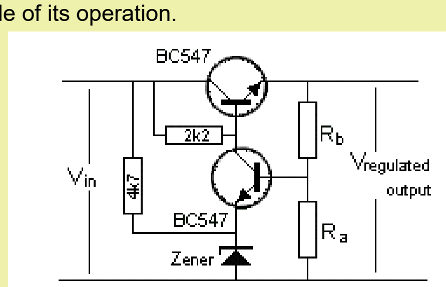


Fig 71bc
2-Transistor Voltage Regulator

THE TRANSISTOR AS AN AF AND RF DETECTOR

A transistor can be used as a "detector" in a radio circuit. The Detector stage in a radio (such as an AM receiver), is usually a crystal, but can be the base-emitter junction of a transistor.
It detects the slowly rising and falling audio component of an RF signal. This signal is further amplified and delivered to a speaker. A single transistor will perform both "detection" and amplification.

In **Fig 71bd**, the first transistor provides these two functions and the output is passed to the second transistor via direct-coupling.
The first two transistors provide enormous gain and a very high input impedance for the tuned circuit made up of the 60t aerial coil and 415p tuning capacitor. The signal generated in the "tuned circuit" is prevented from "disappearing out the left end" by the presence of the 10n capacitor as it holds the left end rigid.

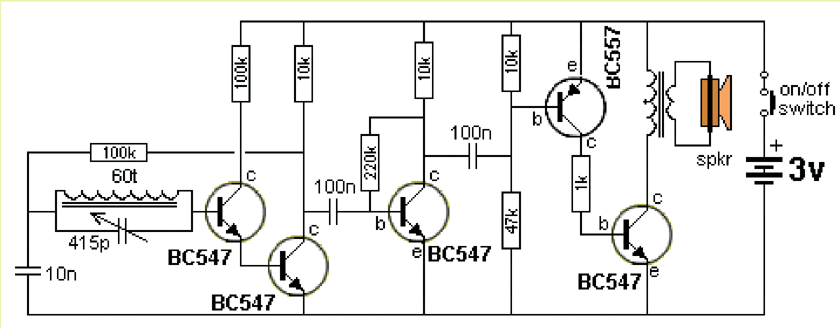


Fig 71bd 5-TRANSISTOR RADIO

THE COUPLING CAPACITOR

We have shown the coupling capacitor transfers very little energy when it does not get fully discharged during part of the cycle and this means it cannot receive a lot of energy to charge it during the "charging" part of the cycle.
This is a point that has never been discussed in any text books. It is the energy (actually the current - due to the difference in voltage between the two terminals of the capacitor) that flows into the capacitor that creates the flow of energy from one stage to the other. It is the "magnet on the door" analogy described previously.
But the question is:
1. How much energy will a capacitor pass under ideal conditions?
2. How do you work out if a capacitor needs to be: 100n, 1u, 10u or 100u?

Without going into any mathematics, we will explain how to select a capacitor.
Many text books talk about the capacitive reactance of a capacitor. This is its "resistance" at a particular frequency.
But an audio circuit has a wide range of frequencies and the lowest frequency is generally selected as the capacitor will have the highest resistance at the lowest frequency.
We will select 200Hz as the lowest frequency for an amplifier.

A 100n will have a "resistance" of about 10k at 200Hz
A 1u will have a "resistance" of about 1k at 200Hz
A 10u will have a "resistance" of about 100R at 200Hz
A 100u will have a "resistance" of about 10R at 200Hz

A 100n capacitor at 200Hz is like putting a 10k resistor between one stage and the next.

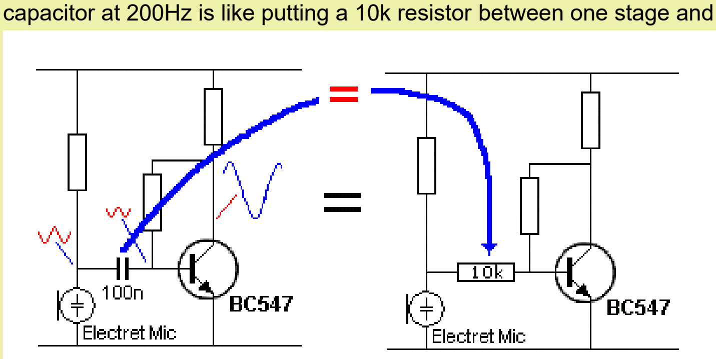


Fig 71c

A 1u capacitor at 200Hz is like putting a 1k resistor between one stage and the next.

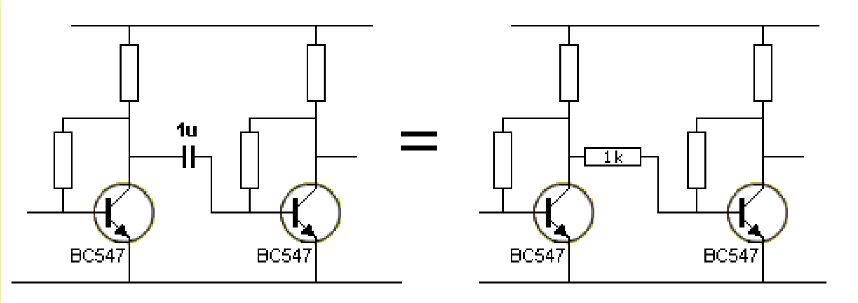


Fig 71d

A 10u capacitor at 200Hz is like putting a 100R resistor between one stage and the next and a 100u capacitor at 200Hz is like putting a 10R resistor between one stage and the next.
In other words, the resistor transfers approximately the same amount of energy as the capacitor but the capacitor separates the DC voltages - the capacitor allows the naturally-occurring voltages to be maintained.

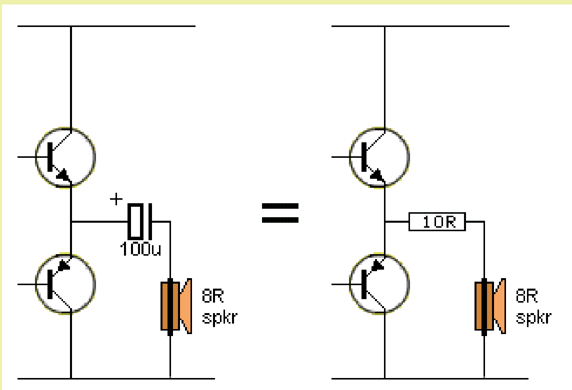


Fig 71e

The capacitive reactance of the 100u ranges from 10R to less than 1R (depending on the frequency being processed).

In **Fig 71d** you can see the "resistance" of a capacitor is very small compared to the LOAD resistance (the main component that determines the amount of energy that can be transferred from one stage to another and the impedance of the receiving stage - the component that determines the discharging of the capacitor). The "resistance" of a capacitor decreases as the frequency increases.
Thus the "capacitive reactance" of a capacitor has very little effect on the transfer of energy from one stage to the next (when it is correctly selected). The major problem is not discharging the capacitor. It only transfers the maximum amount of energy when it is completely discharged.
When it is completely discharged, it acts like a "zero-ohm" resistor during its initial charging-cycle. This is called **INRUSH CURRENT** and can be ENORMOUS. This is the "plop" you hear from some amplifiers when they are turned ON. It is also the inrush current to a power supply. To reduce this enormous in-rush current, a small-value resistor is included in series with the input of the electrolytic(s) in the circuit (or power supply).

Let's go over this again:
The transfer of energy from one stage to another depends on 3 things:
1. The value of the LOAD resistor of the first stage. This resistor charges the capacitor. Its resistance should be as **low as possible** to transfer the maximum energy.
2. The value of the capacitor. It should be **as high as possible** to transfer the maximum energy.
3. The value of the input impedance of the receiving stage. It should be **as low as possible** to discharge the capacitor.

Let's take a 100n capacitor:
In the following circuit, a 100n capacitor separates an electret microphone from the input of a common-emitter stage.

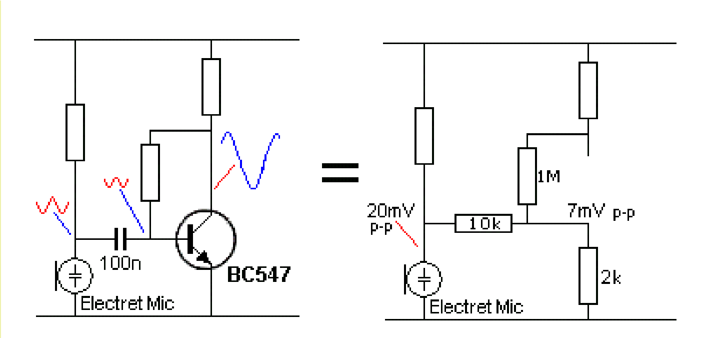
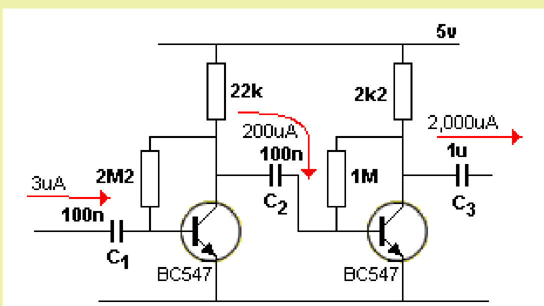


Fig 71f

The waveform on the output of the electret microphone is 20mV p-p (peak-to-peak). This amplitude passes through the 100n capacitor, which we have drawn as a 10k resistor, (to represent the capacitive reactance of the capacitor at 200Hz). The input impedance of the common-emitter amplifier is about 500 ohms to 2k. (500 ohms when the base current is a maximum and 2k when the base current is very small).
The capacitor and the input impedance form a simple voltage-divider, as shown in **Fig 71f.** When a 20mV signal appears on the input of the voltage divider, the voltage at the join of the two resistors will be about 3.3mV.
This is 3.3mV ON TOP of the 630mV provided by the 1M base-bias resistor.
This means about 16% of the waveform gets transferred to the base of the transistor. A common-emitter stage will have a gain of about 70, so 3.3mV input will create 230mV output. It's called a "swing" of 230mV or 230mV P-P (peak-to-Peak) or 230mV AC signal.
But most signals have a frequency of about 2kHz and the capacitive reactance of the capacitor will be about 1k. In this case the transfer will be 66% or 13mV and the output of the stage will be nearly 1v. This is an ideal situation where the capacitor is being fully discharged.
The actual transfer of energy from one stage to another is much more complex than we have described, however you can see it involves the LOAD resistor, the size of the capacitor and the efficiency of discharging the capacitor.
The only way to see the actual result is to view the waveforms on a CRO (Cathode ray Oscilloscope).



TRANSFER OF ENERGY THROUGH THE COUPLING CAPACITOR

It is very difficult to work out how much energy will be transferred by the capacitor coupling the two stages in the circuit above.
As we have mentioned before, the transistor does not transfer very much energy. The first transistor merely pulls the capacitor "down" and this turns OFF the second transistor and discharges the capacitor. But the discharge path is through the base emitter junction of the second transistor and when the base of the second transistor drops below 0.55v, the junction exhibits a very high resistance and does not discharge the capacitor. The base needs to go about 6v negative to exhibit reverse-bias and the 5v circuit does not allow this to occur. So, some slight discharge is done via the 1M resistor. The only other discharge is done when the capacitor is being pulled down and it is still feeding energy into the base of the second transistor.
This loss of energy is not very much and when the capacitor charges again, ONLY the pervious losses can be added to the capacitor and thus it transfers very little energy on the second and future cycles of its operation.
The secret to transferring a lot of energy is to get the capacitor discharged fully during part of the cycle. The 200uA in the circuit above is only a theoretical value for the first cycle, when the capacitor is completely discharged. The second cycle will transfer much LEES than this.

The coupling capacitor passes CURRENT not VOLTAGE

The next point is this: The coupling capacitor does not pass VOLTAGE from one stage to the next but CURRENT.
The voltage on the base of the second transistor may be 0.55v when the capacitor is not passing any energy and rise to 0.65v when passing the maximum energy. This may be equivalent to a 3v signal.
The resistance of the LOAD resistor in the first stage determines how much current will delivered to the capacitor to charge it. In other words, the capacitor converts the voltage (the amplitude of the signal) to CURRENT and the second transistor converts the current to a voltage across its LOAD resistor.

But the energy passed by the capacitor depends on how much it is discharged, as this is the energy (called the charging energy) that will be transferred. There is no way to determine how much energy is discharged on each cycle.
Everyone looks at how much energy (or charge, or current) the capacitor will pass during the "active" part of the cycle or the "forward" part of the cycle, but the most important part of the cycle is the DISCHARGING of the capacitor and when the base of the transistor falls below 0.5v, the capacitor is NOT discharged via the base. This means you have to look-at what is discharging the capacitor. This is the main reason why a particular stage is not amplifying. A diode between base and 0v rail will become forward-biased when the voltage drops below 0v and this can be used to discharge the capacitor.
Now you can see why mathematical calculations in Lecture Notes are SO INACCURATE. Everything is completely different to what you have been told.

INPUT AND OUTPUT IMPEDANCE

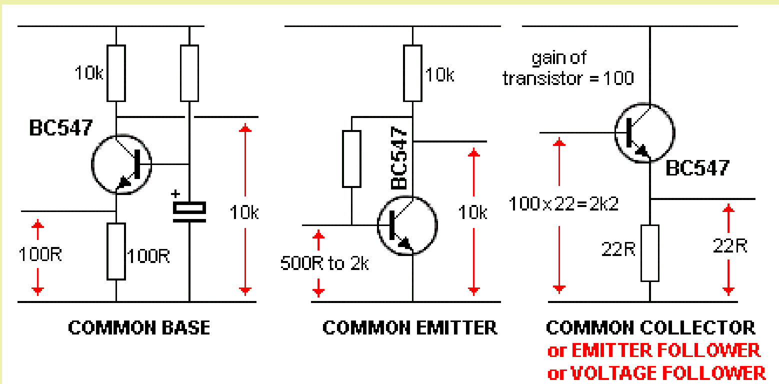


Fig 71g

Fig 71g shows each transistor stage has an input and output impedance. This really means an input and output resistance, but because we cannot measure the value with a multimeter, we have to find the value of resistance by measuring other things such as "waveform amplitudes" and then create a value of resistance, we call IMPEDANCE. The values shown are only approximate and apply to transistors called SMALL SIGNAL DEVICES. The values are really just a comparison to show how the different stages "appear" to input and output devices, such as when connecting stages together.
The input impedance of a common-emitter stage ranges from 500R to 2k. This variation depends on the type of transistor and how much the stage is being turned ON. In other words, the amount of current entering the base.
The value of 2k2 for the emitter-follower depends on the current entering the base.
These values are all approximate and are just to give an idea of how to describe the various values of impedance.

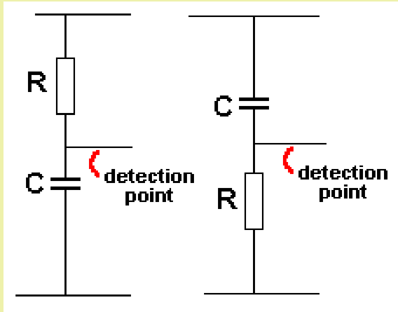
INPUT IMPEDANCE

There are so many discussions in text books on the INPUT IMPEDANCE of a transistor and they are all complex and confusing for the beginner.
Here is a simple explanation.
The transistor is like a FORK-LIFT TRUCK. You move the lever UP and the fork lifts a pallet of bricks.
The same with a transistor, you deliver a small current into the base and the collector delivers a higher current at the collector terminal. This higher current passes through a load (such as a resistor) placed between the collector and the positive rail.
But a transistor can only amplify the current about 100 times. A fork-lift truck can amplify the lever about 10,000 times.
So, don't worry about terms such as IMPEDANCE. All you have to remember is this: The transistor will amplify the current delivered to the base, about 100 times.
Of course you also have to know how much current is being delivered to the base from a previous stage, but that is a problem for another time.
When you place two transistors "on top of each other" to produce a "transistor" called a super-alpha transistor or DARLINGTON transistor, the first transistor amplifies the current by 100 and the second amplifies this current another 100 times, making a total of 100 x 100 = 10,000 and it is as strong as a fork-lift truck !!
Because the first transistor is helping the second transistor, we also say the input impedance is increased by a factor of 100.
But it really all boils down to the fact that the current capability is INCREASED.
There are other facts such as voltage, and amplification will decrease as the current increases, but you can study this AFTER you realise the transistor is simply INCREASES THE CURRENT.

THE TIME DELAY

Also called the TRANSISTOR TIME DELAY or **TIME CONSTANT** or **RC Delay Circuit** or **TIMING**

CIRCUIT.
A Delay Circuit is made with a capacitor and resistor in series:



The TIME DELAY circuit

These are the two components that create the **TIME DELAY**. No other parts are needed. When the value of the capacitor and resistor are multiplied together the result is called the **TIME CONSTANT** and when the capacitor value is in FARADS and resistor in OHMs, the result is SECONDS
To detect when the capacitor has reached about 63% of its final voltage, we need some form of detecting device, such as a transistor.
But the detecting device cannot "steal" any of the current entering the capacitor, otherwise the voltage on the capacitor will never increase or take longer to increase.
We know a transistor requires current for it to operate but a Darlington Pair (or Darlington) requires very little current, so the detecting device must be something like a Darlington.
The transistor plays no part in the timing (or TIME DELAY) of the circuit. It is just a detector.

The main secret behind a good TIME DELAY circuit is to allow the capacitor to charge to a high voltage and use a large timing resistor. This reduces the size of the capacitor (electrolytic) and produces a long time delay.
There are lots of chips (Integrated Circuit) especially made for timing operations (time delays).
Transistors (of the "normal" type - called Bipolar Junction) are not suited for long time delays.
Field Effect Transistors, Programmable Uni Junction transistors and some other types are more suited.
However a normal transistor can be used, as shown in **Fig 71h**.
The normal detection-point is 63% but you can make the circuit "trigger" at any voltage-level. The value "63%" has been chosen because the voltage on the capacitor is increasing very little (each second) when it is nearly fully charged and waiting for it to reach 65% may take many seconds. Trying to detect an extra 10% or 25% is very hard to do and since it takes a long time for the voltage to rise, the circuit becomes very unreliable and very inaccurate. That's why 63% has been chosen.
See also Integration and Differentiation. The same two components (a resistor and capacitor) can be used for a completely different purpose. That's the intrigue of electronics.

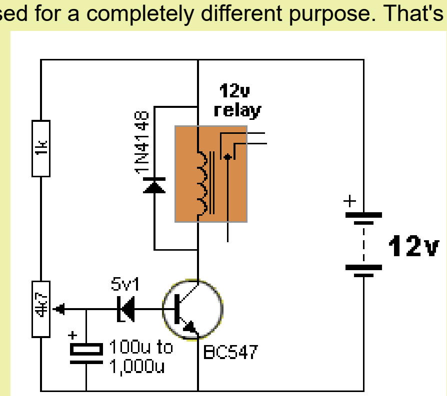


Fig 71h

Fig 71h shows a **TIME DELAY** circuit. This circuit does not wait for the capacitor to charge to 63% but it detects a voltage of 5v1 + 0.7v = 5v8.
The detecting circuit is made up of the 5v1 zener and base-emitter junction of the transistor.
These two components create a high impedance until a voltage of 5v8 because the zener takes no current until its "characteristic voltage" has been reached.

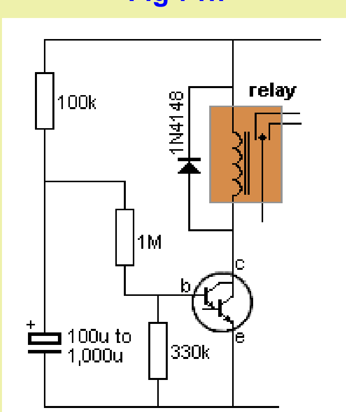


Fig 71j

Fig 71j shows a Time Delay Circuit. The 100k is the time delay resistor. The 1M is the "sense resistor" and the the 330k is the voltage divider resistor.
The base of the Darlington transistor detects 1.4v and the 1M/330k produces a voltage divider that requires 3 x 1.4v = 4.2v on the electrolytic. The 1M, 330k and transistor provide a fairly high impedance detecting circuit that does not inhibit the charging of the capacitor.
The circuit requires a supply of 12v.

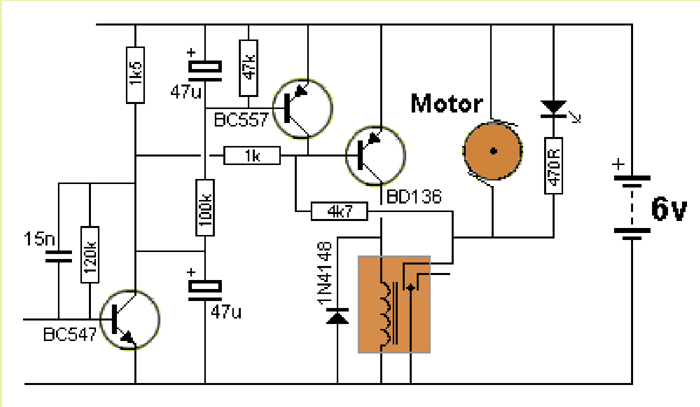


Fig 71k

Fig 71k shows two **Time Delay Circuits** as well as a latching circuit (the 4k7 resistor), a buffer transistor (BD136) and a high frequency filter (the 15n capacitor).
When the circuit is turned **ON**, the relay is not energised. The signal on the base of the first transistor has any high frequency component removed by the 15n capacitor (see below for the effect of a filter on a signal).
The lower 47u is fully charged via the 1k5 a very short time after the circuit is turned on and the output of the first transistor discharges this electrolytic very quickly when it receives a signal.
This turns **ON** the BD136 transistor via the 1k resistor and the relay is energised.
The output of the relay is connected to a 4k7 resistor and this resistor takes over from the effect of the first transistor to keep the relay activated.
If the input signal continues, the top 47u starts to charge and after about 2 seconds, the BC557 transistor turns **ON** and removes the emitter-base voltage on the BD136. This turns the relay **OFF**.

BACK EMF

In some circuits using a relay, you will find a diode has been placed across the coil.
When the relay is turned OFF, it produces a voltage in the opposite direction that can be much higher than the voltage of the supply. This means the voltage appearing on the collector will be higher than some transistors can withstand and they will either zener and absorb the energy or be damaged due to the excess voltage. The diode across the coil is connected so the voltage flows through it and the transistor is protected.
This voltage is called BACK EMF and only occurs when the relay is turned off suddenly when full current (or near full current) is flowing.
The size of the back EMF is due to the number of turns on the coil and the metal in the (magnetic) core. It can be 10 times or even more than the supply voltage and the diode will reduce this to about 0.7v.
Figs 71h,j and k above show a diode across a relay to remove the back EMF and protect the transistor.

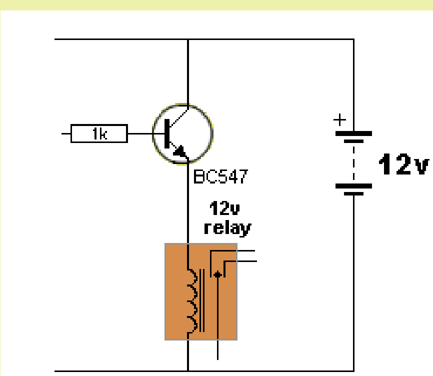


Fig 71m

Figs 71m shows a relay connected in the emitter of a transistor. This configuration is called an emitter-follower. When the transistor turns off, the relay is de-energised and a back-voltage is produced.
The voltage on the top of the relay becomes less than 0v and this pulls the emitter DOWN. This has the effect of turning ON the transistor and for a tiny fraction of a second, the effect of the relay is cancelled by a flow of current through the transistor. This prevents a high back-voltage being produced and thus a diode is not needed.

One point about emitter-follower designs:
The voltage on the relay is less than 12v due to the 0.7v between the base and emitter and the base will be lower than 12v by as much as 1v. Compare this with the common-emitter driver where the collector-emitter drop will be as low as 0.4v.

Back EMF is also produced by motors and is known as "commutation noise." This "noise" can also be suppressed via a capacitor and/or small inductors in the leads. The size of the voltage must be measured when the circuit is operating as it is a "spike" and this spike will puncture a semiconductor (such as a transistor).
Back EMF is also produced by coils, called INDUCTORS. An inductor is also called a choke.
When a piezo is placed across an inductor, and a signal is delivered to the parallel-pair, the piezo will detect the high-voltage (Back EMF) and produce a very load output. The inductor produces the high voltage when the signal is turned off sharply. The magnetic flux collapses and produces a very high reverse voltage. A typical circuit that takes advantage of this high voltage is the: Wailing Siren

HIGH FREQUENCY "NOISE"

Before we move on to the next phase of this discussion, there is one interesting point that needs

covering.
When a circuit has a number of amplifying stages, there is always a possibility of noise being generated in one of the transistors in the "front-end" (the first or second stage in the amplifier) and this is amplified by the stages that follow. This is the case with the Hearing Aid Amplifier in **Fig 69**.

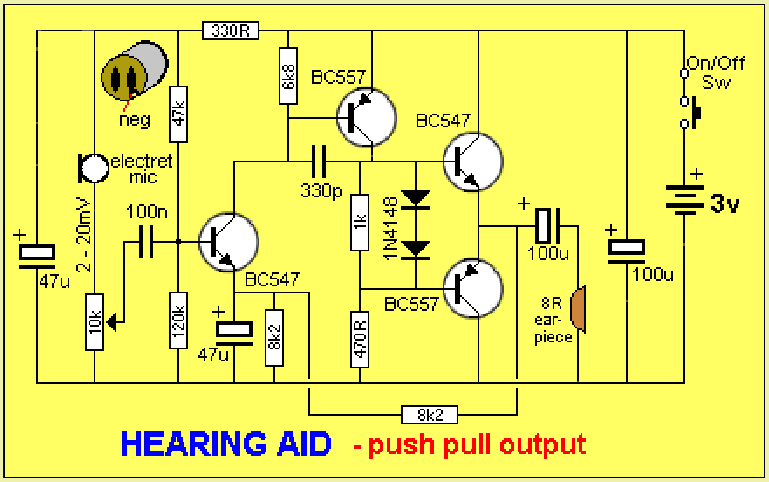


Fig 69.

The 330p between the base and collector of the BC557 removes high-frequency noise. If the 330p is removed a 1MHz waveform is generated in the front-end and amplified by the stages that follow. This noise cannot be heard but is visible on a CRO (Cathode Ray Oscilloscope) and causes the circuit to take extra current. The 330p capacitor provides **NEGATIVE FEEDBACK** to remove the waveform completely.

FILTERS

We have studied circuits that use components to produce NEGATIVE FEEDBACK. The first circuit we studied was the self-biased common-emitter stage. The base-bias resistor provided negative feedback to set the voltage on the collector.
Any component (resistor or capacitor) connected between the output and input of a stage produces NEGATIVE FEEDBACK.
A **resistor** connected between the output and input produces about the same amount of feedback no matter what frequency is being process by the amplifier.
But a **capacitor** provides more feedback as the frequency increases. That's because the effective "resistance" of the capacitor decreases as the frequency increases.
This feature can be used to "kill" the amplitude of high frequencies and thus only allow low frequencies to be amplified.
It can also be used to only allow high frequencies to be amplified. When it is used to couple two stages, a **low-value** capacitor will only allow high frequencies to pass from one stage to the next.
By using a resistor in series with a capacitor, the effect of the capacitor can be controlled.
Using these facts, we can design circuits that will amplify low frequencies or high frequencies. This type of circuit is called a FILTER.
A Filter can be given a number of names. Here are a few:
Active Filter contains a transistor or op-amp in the circuit
High Pass Filter suppresses or rejects the low frequencies Only the high frequencies appear on the output
Low Pass Filter suppresses or rejects the high frequencies Only the low frequencies appear on the output
Notch Filter: A Filter that rejects or suppresses a narrow band of frequencies.

To understand how a filter works, you need to know "**HOW A CAPACITOR WORKS**."

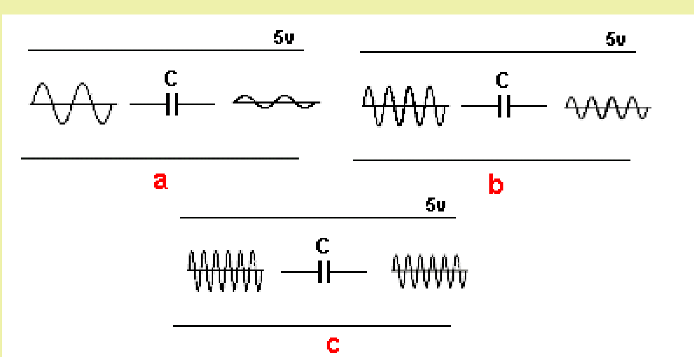


Fig 72a.

Fig 72a shows a capacitor with a low-frequency signal entering the left terminal.
The output amplitude from the capacitor in diag **a** will be small because the capacitor is able to charge and discharge as the signal rises and falls.
As the frequency of the signal increases, the output increase in amplitude because the capacitor does not have enough time to charge and discharge and thus it does not "absorb" the amplitude of the signal.

Fig 72b shows a capacitor connected between the "signal line" and 0v rail. When a low-frequency signal is on the "line," the capacitor has little effect on attenuating (reducing) the

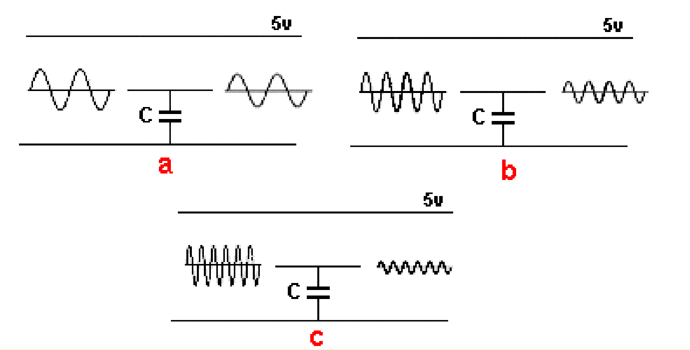


Fig 72b.

amplitude, as shown in diag a because the capacitor charges and discharges just like pushing a "shock absorber" up and down **slowly**.
As the frequency of the signal increases, it is reduced in amplitude because the signal is trying to charge and discharge the capacitor very quickly and it takes **energy** to do this and the energy is coming from the signal.

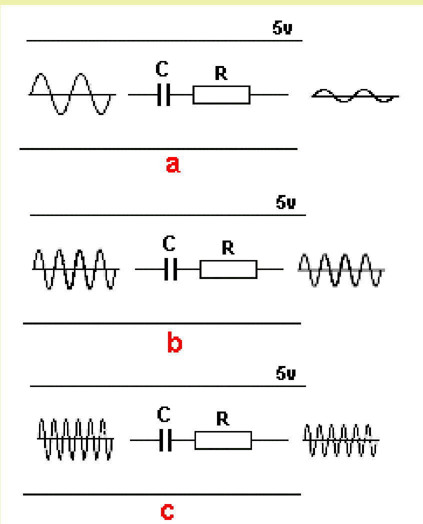


Fig 72c.

Fig 72c **Fig a** shows a capacitor and resistor connected in series on the "signal line." With a low-frequency signal, the capacitor reduces the amplitude because most of the signal is absorbed by the capacitor charging and discharging.
As the frequency increases (**fig b**), the output will be reduced by a smaller amount because the capacitor has less time to charge and discharge and less time to "absorb" the signal.
As the frequency is increased further **(fig c)**, the resistor starts to have an effect on reducing the amplitude because these two components are connected to other components in a circuit and a higher frequency has a higher energy and more of this energy gets lost in the resistor - thus reducing the amplitude slightly.
In addition, the capacitor is already charging and discharging as quickly as possible and it is transferring as much of the signal as possible. It is only the resistor that is creating the attenuation at high frequencies.
It does not matter if the capacitor or resistor is placed first or last, the attenuation is the same.

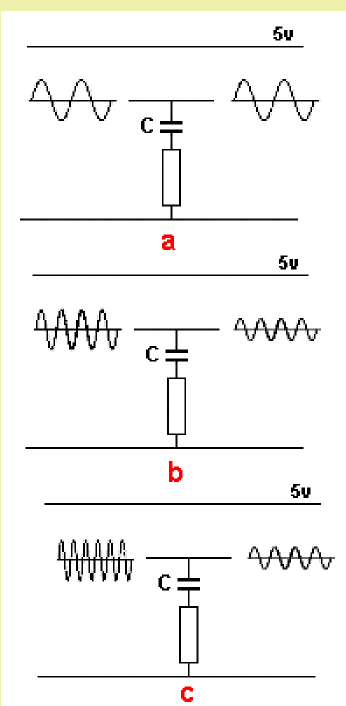


Fig 72d.

Fig 72d **Fig a** shows a capacitor and resistor connected in series between the "signal line" and 0v rail. With a low-frequency signal the capacitor can charge and discharge and the voltage across it will rise and fall so the effect on the amplitude of the signal is minimal.
The resistor has very little effect on reducing the amplitude.
The top plate of the capacitor rises and falls with the signal and the bottom plate rises and falls very little.

As the frequency increases, the capacitor cannot charge and discharge fast enough and more of the energy of the signal goes into charging and discharging it. The top plate of the capacitor is rising and falling very quickly and this is making the lower plate rise and fall a small amount. This puts a small current though the resistor and this has an effect on reducing the amplitude.
The amplitude of the output is reduced as shown in Fig b.

As the frequency is increased further as shown in dia c, the top plate of the capacitor is rising and falling as fast as it can and the lower plate is rising and falling too. This puts most of the amplitude-loss in the resistor but the signal is not reduced any more.
It does not matter if the capacitor is above or below the resistor, the attenuation is the same.

Once you have a concept of the way a capacitor reacts to a high and low frequency, you can see how a circuit will pass or prevent (attenuate) a signal.
There are many different types of filters and they are all designed to improve the output of a poor signal, such as removing background "hiss" or "rumble" in audio recordings.
The following two circuits show the effect of adding capacitors and resistors between the output and input:

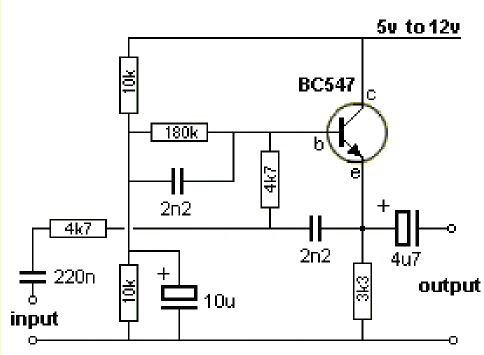


Fig 72e.

Fig 72e is a low-pass filter that provides unity voltage gain to all frequencies below 10KHz, but it rejects all frequencies above 10KHz at 12dB per octave. It is used to remove high frequency noise from audio recordings.

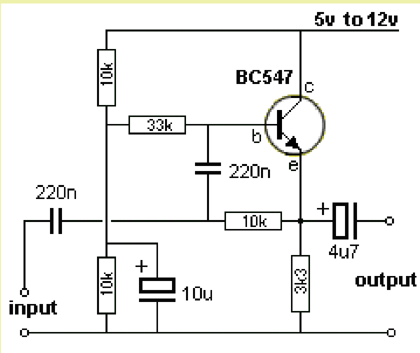
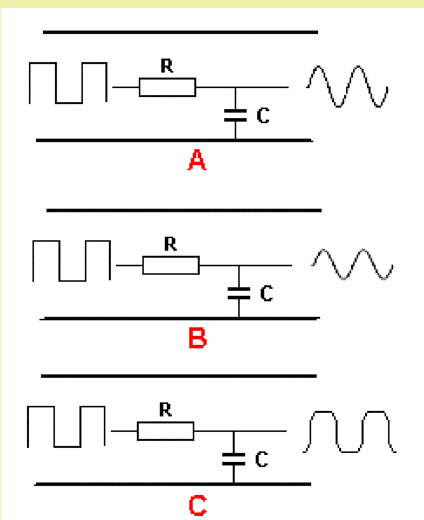


Fig 72f.

Fig 72f is a high-pass filter that provides unity voltage gain for all frequencies greater than 50Hz. However, it provides 12 dB per octave rejection to all frequencies below 50Hz. It is used to remove low frequency noise from audio recordings.
The transistor is configured as an emitter-follower biased at about half the supply value by the low-impedance junction formed by the top 10k resistor and the lower 10k in parallel with the 10u electrolytic.
Negative feedback applied through the filter network of the 33k and 220n and the 10k and 220n creates an *active* filter response.

SQUARE-WAVE TO SINEWAVE



Square-wave to Sinewave

Converting a square wave to a sinewave can be done with a capacitor and resistor in series.
The capacitor takes time to charge and discharge, (according to the value of the resistor) and the output of the circuit is where the two components join.
The circuit is actually a **TIME DELAY** circuit, but this time we are monitoring the rise and fall of voltage on the capacitor, rather than just detecting the value after a period of time.
The Square-wave to Sinewave circuit is drawn slightly different to the Time Delay circuit so you can see what is happening.
The resistor is drawn at an angle of 90 degrees to the capacitor to show the signal is attenuated (reduced) in the resistor and appears across the capacitor as an amplitude.
The value of the resistor and capacitor are important.
When they are the correct values, the signal is a very-good sinewave with maximum amplitude as shown in diagram **A**.
When the values are too high or too low, the result is shown in figures **B** and **C**. .

THE "DIGITAL" STAGE - or Digital State also called the DIGITAL CIRCUIT or DIGITAL TRANSISTOR

There is no such thing as a **DIGITAL TRANSISTOR** or an **AUDIO TRANSISTOR**.
All transistors are just "**TRANSISTORS**" and the surrounding components make the transistor operate in **DIGITAL MODE** or **ANALOGUE MODE**.
It's a bit like saying money is: "food money" or "petrol money."
But we have some transistors that have inbuilt resistors to make it suitable for connecting to a digital circuit without the need for a base resistor.
Here is the datasheet for an NPN transistor BCR135w and PNP datasheet for BCR185w.
These transistors are called "**Digital Transistors**" because the "base lead" can be connected directly to the output of a digital stage. This "lead" or "pin" is not really the base of the transistor but a 4k7 (or 10k) resistor connected to the base allows the transistor to be connected to the rest of a digital circuit.

You cannot actually get to the base. The resistor(s) are built into the chip and the transistor is converted into a "Digital Transistor" because it will accept 5v on the "b" lead. The 47k is not really needed but it makes sure the transistor is fully turned OFF if the signal on the "b" lead is removed (in other words - if the input signal is converted to a high-impedance signal - see tri-state output from microcontrollers for a full explanation). This transistor is deigned to be placed in a circuit where the input changes from low to high and high to low and does not stop mid-way. This is called a DIGITAL SIGNAL and that is one reason why the transistor is called a digital transistor. (However you could stop half-way but the transistor may heat up and get too hot).
Any transistor placed in a digital circuit can be called a "digital transistor" but it is better to say it is operating in **DIGITAL MODE**.

All the circuits and stages we have discussed have been amplifiers for audio signals.
However there is another signal that can be processed via an amplifier. It is called a digital signal or "Computer" signal. It is a signal that turns a transistor ON fully or OFF fully.
The simplest example of a digital circuit is a torch. The globe is either ON or OFF. But a torch does not have any transistors. We can simply add a transistor and the circuit becomes DIGITAL CIRCUIT.
A Digital Circuit has 2 STATES: ON and OFF. It is never half-ON or half-OFF.

The secret to turning a transistor ON fully is base current. If you supply enough base current the transistor will turn ON FULLY.
The Digital Circuit is the basis of all computers. It produces an outcome of "0" when not active or "1" when active. This is called POSITIVE LOGIC.

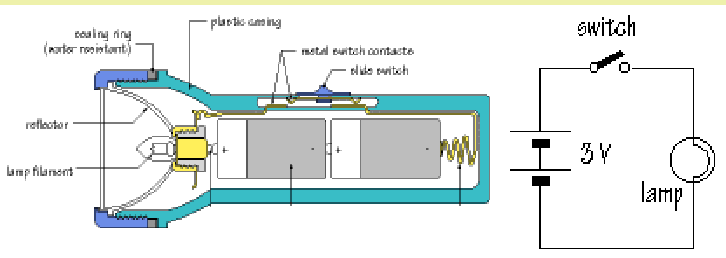


Fig 72. A TORCH is an ON-OFF circuit.
A Digital circuit is an ON-OFF circuit.

Fig 72.

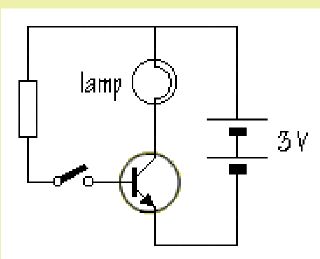


Fig 73. This is the simplest DIGITAL CIRCUIT. The globe illuminates when the switch is closed.
Whenever a transistor is used in a stage that has a defined ON state and OFF state, it is using the OFF and ON state of the transistor and the transistor is called a **DIGITAL TRANSISTOR**.
It is simply an ordinary transistor used in a "**DIGITAL WAY**."
It is **NOT** a special type of transistor.

Fig 73.

Two reasons why a Digital Circuit was invented:
1. It produces either "0" or "1" (LOW or HIGH) and these are accurate values. By combining millions of "digital circuits" we can produce counting and this is the basis of a computer.
2. When a circuit is OFF, it consumes no power. When a circuit is fully ON the transistor also consumes the least power. This is because the globe is illuminated brightly and the transistor remains cool - as it has the lowest voltage across it.
The "ON" "OFF" states are called LOGIC STATES or DIGITAL STATES and when two transistors are put together in a circuit with "cross-coupling" they alternately flash one globe then the other.

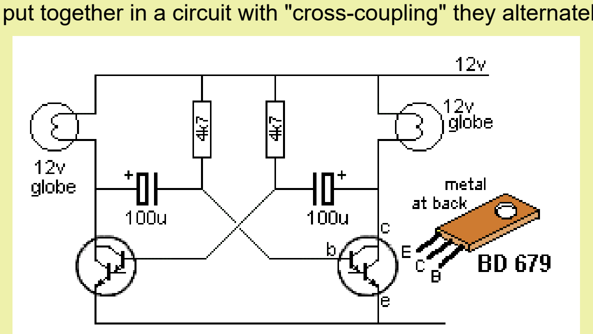


Fig 74. This circuit is called a **FLIP FLOP** or **ASTABLE MULTIVIBRATOR**.
(AY-STABLE - meaning not stable)

Fig 74.

THE TRANSISTOR AS A SWITCH

Using a transistor as a switch is exactly the same as using it in **DIGITAL MODE** or in a **DIGITAL**

CIRCUIT or in a **LATCH CIRCUIT** or any other circuit where the transistor changes from OFF state to ON state VERY QUICKLY.
A transistor in this type of circuit is called a **SWITCHING TRANSISTOR** and it may be an ordinary audio transistor but it is called a switching transistor when used in a switching circuit.
The two Darlington transistors in **Fig 74** are SWITCHING TRANSISTORS and the circuit is an **ASTABLE MULTIVIBRATOR.**
One of the most common circuits is used to activate a relay. A relay must be turned ON or OFF. It cannot be half-on or half-off. The transistor changes from OFF to ON very quickly. It is called a switching transistor.
All transistors used in a **DIGITAL CIRCUIT** are switching transistors. **DIGITAL CIRCUITS** or **DIGITAL LINES** are either **HIGH** or **LOW**.
When a digital transistor is turned **ON** (saturated) the output is LOW. When a digital transistor is **OFF** the output is HIGH. The output is taken from the collector of a common-emitter stage.
This is called two MODES of operation. **ON** and **OFF**.
Any circuit that operates in **TWO MODES** is called a **DIGITAL CIRCUIT**.

DRIVING A RELAY

Any circuit that drives (powers) a relay is essentially a DIGITAL CIRCUIT. Sometimes the driving circuit can gradually turn ON and when the collector current is sufficient, the relay pulls-in.
When the collector current falls to a lower value, the relay drops-out.
We like to think of the driver stage as a digital stage so that we guarantee the relay will pull-in and drop-out.
Here's an important feature that has never been mentioned before:
A relay must pull in quickly and firmly so the contacts close with as much pressure as possible. This prevents arcing when closing and opening and ensures a long life for the relay.
That's why the driver circuit should be an ON-OFF or DIGITAL design.
The following circuits are NOT high-speed, but will activate a relay successfully.

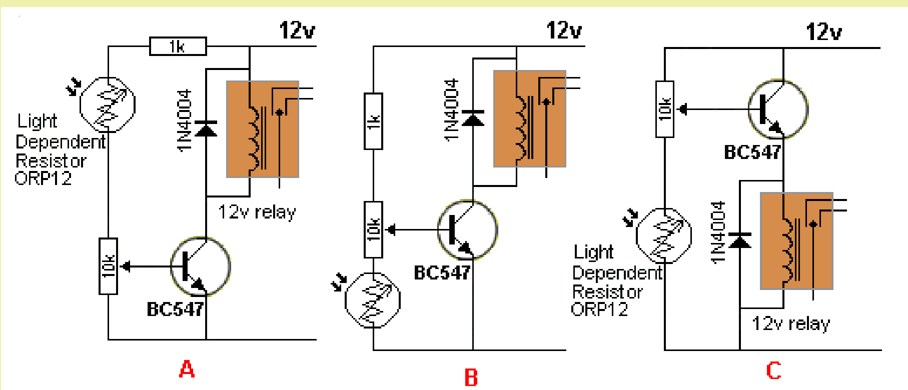


Fig 74a.

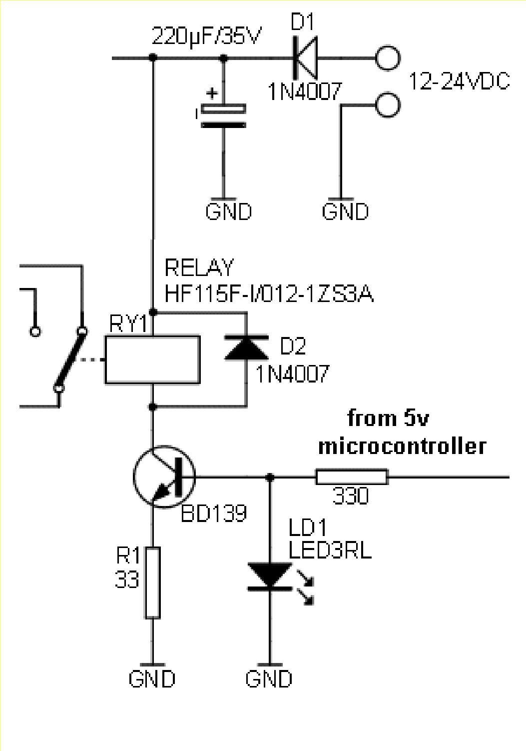
Circuit **A** activates the relay when light falls on the LDR. The level of illumination can be adjusted by the 10k pot.
Circuit **B** activates the relay when the illumination reduces. The level can be adjusted by the 10k pot.
Circuit **C** is an emitter follower and although it works in a similar way to circuit B, the voltage on the collector is less than 12v by about 1v and this creates extra loss and added temperature-rise in the transistor.

A 12v relay ***might*** work on a 9v circuit, but as we said above, the relay needs to close with as much pressure as possible to prevent the contacts arcing.
A 6v relay will work on a 12v circuit if you add a 5v1 or 5v6 zener in series with the coil.
A 12v relay will work on a 24v circuit if you add a 12v zener.
If the driver transistor turns on and **OFF** very fast, you will need a diode across the coil to prevent the back voltage damaging the transistor when the relay turns OFF.
The circuits above operate very slowly and a diode is not needed.

DRIVING A RELAY via CONSTANT CURRENT

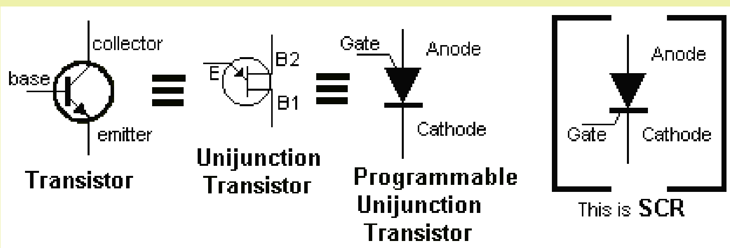
A relay can be driven by a circuit called a **CONSTANT CURRENT CIRCUIT** and this means the maximum current delivered to the relay is fixed by the driving transistor. This means the supply voltage can rise higher than the recommended voltage and the relay will still be supplied with its rated coil current.
The circuit can also be called **CURRENT LIMITING** or **CURRENT CONTROLLING** or **MAXIMUM CURRENT**.
For this circuit to work you must know the current required by the coil for it to pull-in effectively.
This value can be obtained from the specification sheet for the relay. It will specify the coil voltage and the coil resistance.
In our example the coil is 12v and the resistance is 360 ohms. This identifies the relay as requiring 33mA to close the contacts.

Most relays will work on a slightly lower voltage and slightly higher voltage, but if the supply ranges from 12v to 24v, you need this type of circuit:

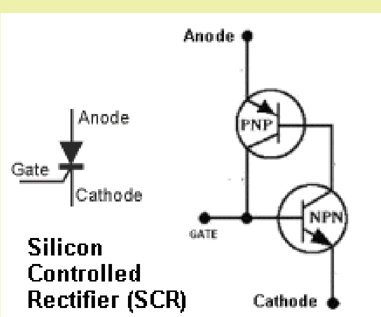


The BD 139 only allows (a maximum of) 33mA to flow because the base sees 1.7v due to the characteristic of the red LED.
The voltage between base and emitter is 0.7v and this means 1v will be dropped across the 33R when the current rises to 33mA.
Suppose you fit a relay requiring 100mA. If it is a 12v relay, it will have about 120R coil.
The transistor will turn ON and the current will increase. As soon as the current reaches 33mA, the voltage across the 33R will be 1v and since the transistor is only seeing 1.7v on the base, if the current rises any further, the voltage across the 33R will rise and the voltage between base and emitter will be less than 0.7v. This will cause the transistor to turn OFF slightly.
This means only 33mA will flow through the relay and it will not be enough to close the contacts. The relay will not work.
If you increase the supply from 12v to 24v, the current will not rise above 33mA and the relay will still not work.
If you fit the 33mA relay and increase the voltage from 12v to 24v, only 33mA will flow though the relay and 12v will appear across it. The other 11v will appear across the collector-emitter terminals of the transistor and 1v will be across the 33R.

THE UNIJUNCTION TRANSISTOR etc

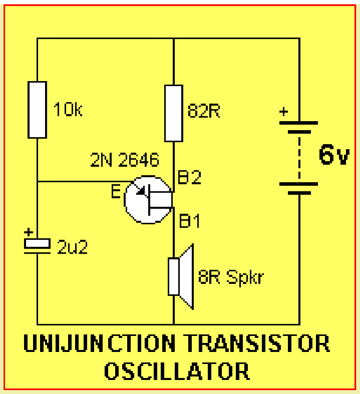


The Unijunction Transistor (UJT) and the Programmable Unijunction Transistor (PUT) and the ordinary transistor ARE ALL THE SAME.
A voltage on the base or the "E" lead or the Gate, will turn them all on and the resistance between all the leads will reduce to a small value. Actually a small voltage will develop between the leads and this is called a characteristic voltage and cannot be altered.
BUT here are the differences. The voltage on the base of the ordinary transistor is about 0.7v to turn it ON. The voltage on the Unijunction Transistor can be up to 3.5v The voltage on the Gate for the PUT is about 0.7v and can be slightly higher or lower.
When the voltage is removed from the base, "E", or Gate, the device "turns OFF."
If you add a voltage divider to the base of the ordinary transistor, you can turn it on at say 1v or 2.6v or any value. You can call this "programming the transistor"
That's what a Programmable Unijunction Transistor is. It is an ordinary Unijunction Transistor that can be placed in a circuit with voltage divider resistors so the device turns on at a particular voltage.



A Silicon Controlled Rectifier has a different feature. When the voltage on the Gate turns the SCR ON, it "latches" and stays ON until the supply voltage is removed and the current through the SCR falls to zero.
The two diagrams opposite are NOT identical. The SCR remains "latched" via the Gate. Making the Gate 0v, will not unlatch the SCR.

The UJT circuit shows a typical arrangement with a low-impedance device, such as a speaker, between B1 and 0v rail. The way it works is this: The capacitor charges via the 10k resistor. During this time the resistance between B1 and B2 is infinite. The charging is a sawtooth waveform because the charging is a rising gradient and the discharge is very rapid - into the speaker. The emitter detects when the voltage rises to about



3.5v to 4v (this is a characteristic of the UJT device) and at this point the transistor "turns on" and the resistance between the Emitter and B1 becomes very low and is effectively equivalent to a diode in forward-bias. The voltage (the energy) in the capacitor is then passed to the speaker and this produces a "click." This is the only way the speaker gets its energy. The voltage across the capacitor falls very rapidly and when it reaches less than 0.7v, the transistor turns off and the cycle repeats.

Why can't you use an ordinary transistor in the circuit above?

Because an ordinary transistor turns ON slowly when the voltage is 0.55v and turned on more at 0.6v and turned ON fully at about 0.7v. There is only a very small "gap" between 0.55v and 0.7v and this would be the charging and discharging voltage for the electro. But during this range the transistor is turning ON too and effectively removing the charging capability of the 10k to charge the electro and thus the circuit would never work.
You can't use an SCR because it "latches" and the cycle will not repeat.

One of the main differences between Unijunction and PUT:

A Unijunction Transistor needs about 2v to 3.5v to turn ON.
A **P**rogrammable **U**nijunction **T**ransistor turns on at 0.2v to 1.6v (normally 0.5v to 0.7v)

LATCH CIRCUIT - an SCR made with transistors

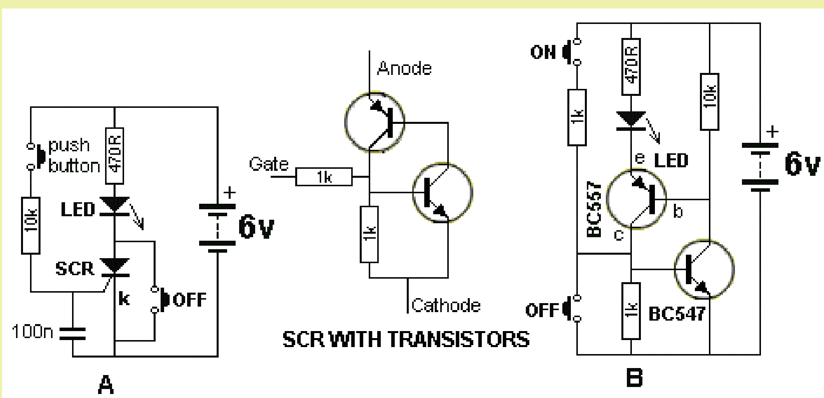


Fig 75. Latch Circuit

Fig 75. Circuit B is a LATCH. The two transistors instantly change from the OFF state to the ON state. This is also classified as a DIGITAL CIRCUIT. The circuit can also be called an SCR made with transistors. Circuit A shows an SCR in action. The top switch turns the SCR ON and it stays ON when the button is released. To turn the SCR off, the lower switch is pressed.
The SCR in circuit A produces a 'LATCH.'
The SCR can be replaced with two transistors as shown in circuit B.

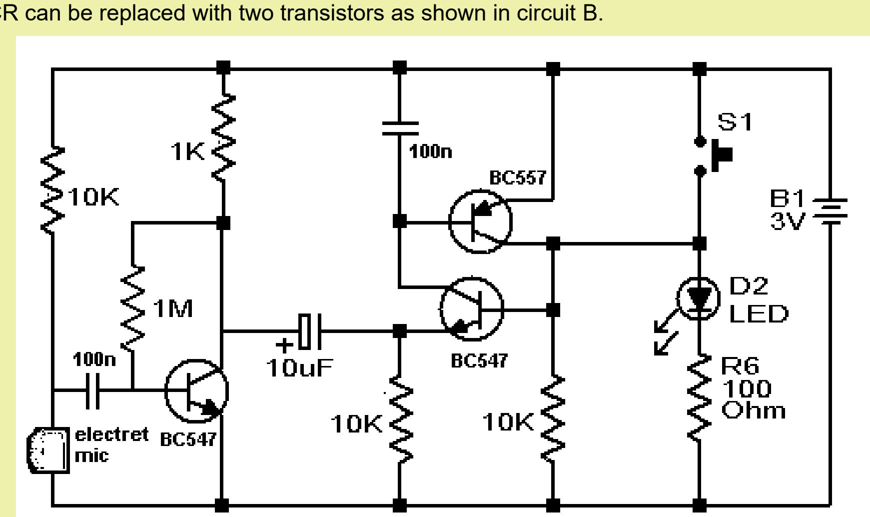


Fig 75aa. Latch Circuit

Fig75aa is a LATCH and the PNP/NPN transistors are "latched-on" by pressing S1. The circuit will also

turn on with a resistor as high as 15k across S1 as we only need to put 0.6v on the base of the BC547 transistor. The 10k on the base forms a voltage divider and this determines the resistance of the "turn-on" resistor. The emitter of the BC547 transistor does not move when this voltage is applied and the collector of the BC547 pulls the base of the BC557 down to turn the PNP transistor ON. This action takes over from the 15k resistor and the two transistor remain ON.
The base of the BC547 is pulled to nearly rail voltage and the emitter is 0.6v lower. The 10u electrolytic charges to cater for the voltage-difference between the collector of the first transistor and the voltage on the emitter of the BC547.
When the first transistor turns on, the voltage on the collector reduces and this pulls the positive lead of the 10u towards the 0v rail.
The negative lead of the 10u cannot fall as it is connected to the emitter of the BC547.
This means the 10u discharges and when the first transistor turns off, the positive lead rises and takes the negative lead with it. This reduces the voltage on the emitter of the BC547 and the transistor turns OFF.
This is how the LED turns off.
Further blowing into the microphone will make the emitter lead of the BC547 rise and fall and this will make the LED flicker, just like trying to blow out a candle.

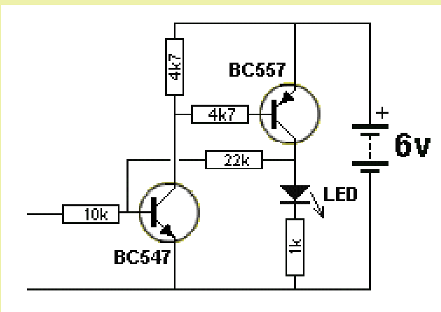


Fig 75a. Latch Circuit

Fig 75a. This circuit is a LATCH. The two transistors instantly change from the OFF state to the ON state when the input voltage rises above 0.6v
The 22k **POSITIVE FEEDBACK** resistor keeps the circuit **ON** when the input voltage is removed.
The 6v supply must be removed to turn the LED off.

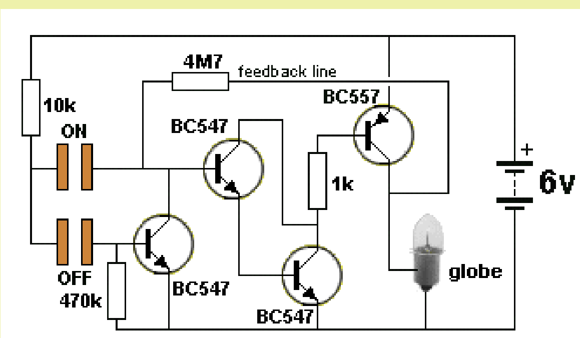


Fig 76. Touch Switch

Fig 76. This is a circuit of a TOUCH SWITCH. Touching the "ON" pads turns ON the second and third transistors as they are a SUPER-ALPHA PAIR or DARLINGTON arrangement and have a very high input impedance and very high gain. The output of this pair goes to a PNP transistor that amplifies the 5mA current from the Darlington to deliver 250mA to the globe.
A feedback line from output to input via a 4M7 keeps the circuit ON when your finger is removed and provides a "Keep-ON" voltage (and current).
The first transistor removes this **"Keep-ON" voltage and current** when a finger is placed on the OFF pads. .

How can you tell a **DIGITAL CIRCUIT** from an **ANALOGUE CIRCUIT?**
1. Absence of capacitors. There are **NO** capacitors in a **DIGITAL CIRCUIT.**
2. A switch or push-button will be activating the circuit.
3. The circuit will be driving a **DIGITAL** or **ON - OFF** item such as a relay or globe.

The two states of a transistor in a **DIGITAL CIRCUIT** are: OFF - called "**CUT-OFF**" and ON - called "'**SATURATION**."
To saturate a transistor the base current is simply increased until the transistor cannot turn on any more. In this state the collector-emitter voltage is very small and the transistor can pass the highest current and the losses (in the transistor) are the lowest.

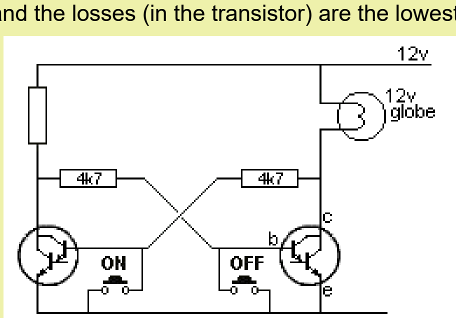


Fig 77. This circuit has only two states. ON and OFF. The ON button turns off the first transistor so the second transistor turns the globe ON.
This is called a TOGGLE ACTION and the circuit is a BINARY CIRCUIT or BISTABLE CIRCUIT called a BISTABLE SWITCH or a bistable of the MULTIVIBRATOR family (**BISTABLE MULTIVIBRATOR**).
It can also be called a LATCH as it stores **one bit of information** and is the basis of a COMPUTER.

Fig 77.

ILLUMINATING A GLOBE (Lamp)

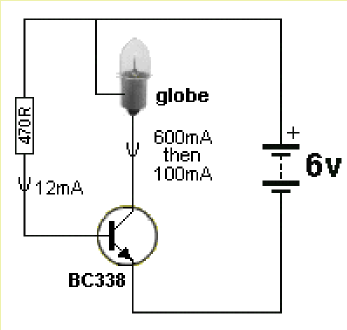
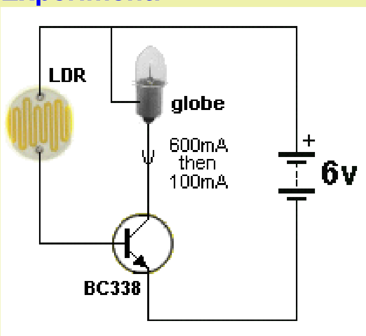


Fig77a. The base needs 12mA to "turn on" the globe

Illuminating a globe is not easy. A globe (lamp) takes 6 times more current to get it to start to glow because the filament is cold and its resistance is very low.
For instance, if a lamp requires 100mA, it will take 600mA to get it to start to glow.
This means the transistor must be capable of delivering 6 times more current and when the filament is glowing, the current will reduce to 100mA.
This means a transistor capable of delivering 800mA (BC337, BC338) will be sufficient for the job, however the gain of the transistor will have to rated at 50 because the current is getting near to the maximum.
The base current will have to be 600/50 = 12mA.
You need to supply the base with 12mA and the lamp will illuminate. When the lamp is glowing, the transistor only needs about 1-2mA, however it is difficult to reduce the current to the base and if the 12mA is supplied to the transistor, it simply means that 2mA will be used by the transistor and 10mA will pass through the base-emitter junction and be wasted.

Experiment:



Shine a light on the LDR and the globe will gradually get brighter.

You can change the 470R in the diagram above for an LDR (Light Dependent Resistor) and watch the globe illuminate.
The LDR chosen for the experiment has a resistance of 300k when in the dark and about 100 ohms when a bright light is shone on it. Do not shine a light too close to the LDR as its resistance will be so low that a very high base current will flow.
If the circuit does not work, the globe requires more than 600mA to get it to start to glow or 100mA when fully illuminated.

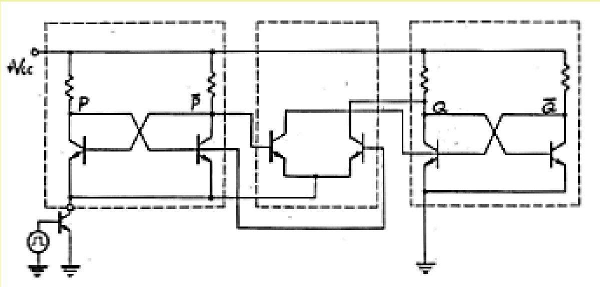


Fig 77b.

Fig 77b. This is part of a counting circuit and since it takes many transistors to create a circuit to count to "2" it is not practical to make it using discrete components. That's why INTEGRATED CIRCUITS were invented where dozens, then hundreds then thousands then millions of transistors are connected to produce counting chips and "bit-storing chips" and many other requirements.

Before we cover our next type of circuit, we will explain a 2-transistor directly-coupled arrangement from Figs 52 and 66. It is interesting as it can be used as a digital circuit or an analogue circuit.

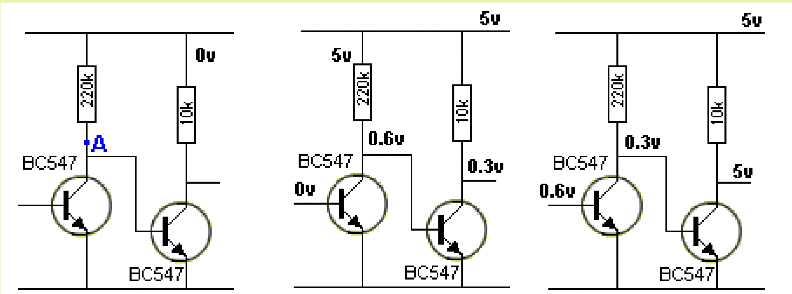


Fig 78.

Fig 78. Two facts to note:
1. Point "A" never rises above 0.6v as it is connected to the base of the second transistor.
2. When the first transistor is turned ON, the collector-emitter voltage is 0.3v and the second transistor is OFF - this is because the base of the second transistor needs 0.6v to turn ON.
In other words, when one transistor is **ON** the other is **OFF**. There is a very brief change-over point where the first transistor turns ON a little more and the second transistor turns OFF a very large amount. If you can find and maintain this change-over point, the two transistors will work in analogue

mode with high gain but if you pass this point very quickly, the two transistors will operate as a switch in DIGITAL MODE.
We can turn this circuit into a DIGITAL CIRCUIT. The secret to doing this is FEEDBACK and the name of the circuit is a **SCHMITT TRIGGER:**.

THE SCHMITT TRIGGER

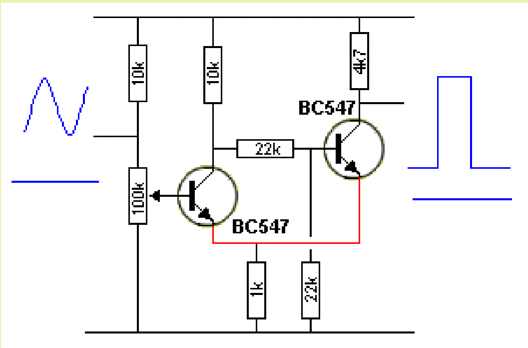


Fig 79a. Schmitt Trigger Circuit

Fig 79a. A **Schmitt Trigger** takes a slowly rising or falling voltage and turns it into a fast-acting ON-OFF signal. The secret is the feedback line shown in red.
The circuit can also be called a "sinewave-to-square-wave generator."
When the input is LOW the output is LOW.
It is a form of bi-stable multivibrator.
The distance between the lower voltage and the upper voltage (at which the circuit changes state) is called the **HYSTERESIS GAP**. This can be widened or narrowed via the 1k resistor (the 100k pot needs to be re-adjusted when the 1k is changed).

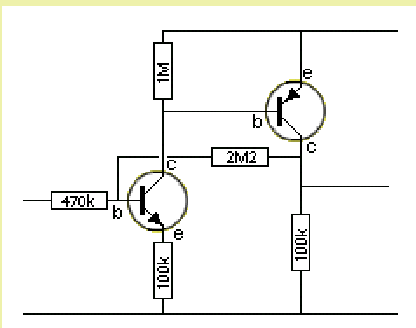


Fig 79aaa. Basic Schmitt Trigger

Fig 79aaa. The basic **Schmitt Trigger** only needs 3 resistors. This is shown in **Fig 79aaa.**
When the first transistor is conducting (turned ON) and the second transistor is OFF, a voltage develops across the 1k due to the collector-emitter current of the first transistor.
When the first transistor turns OFF, about the same current flows though the 10k collector-load, through the base of the second transistor, plus current flows through the 4k7 load resistor.
This means about three times more current flows through the 1k emitter resistor and thus the voltage across it will increase about 3 times.
This is the **HYSTERESIS** voltage of the circuit.

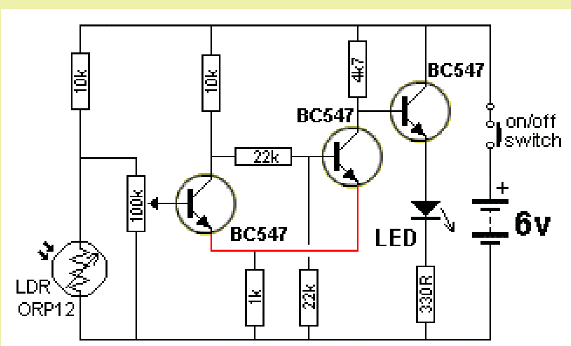


Fig 79. Schmitt Trigger Circuit

Fig 79. This circuit takes a slowly rising or falling voltage and turns it into a fast-acting ON-OFF signal to operate a LED or relay.
This is done via the positive feedback line shown in red. It is called positive feedback because it ADDS to the change to speed it up.
This circuit is fully explained in the:
Talking Electronics website CD.

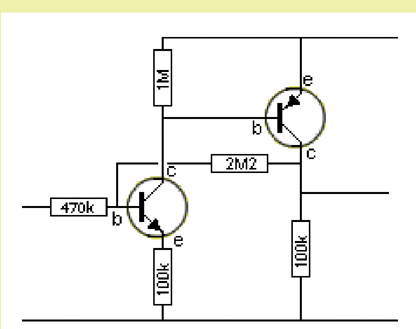
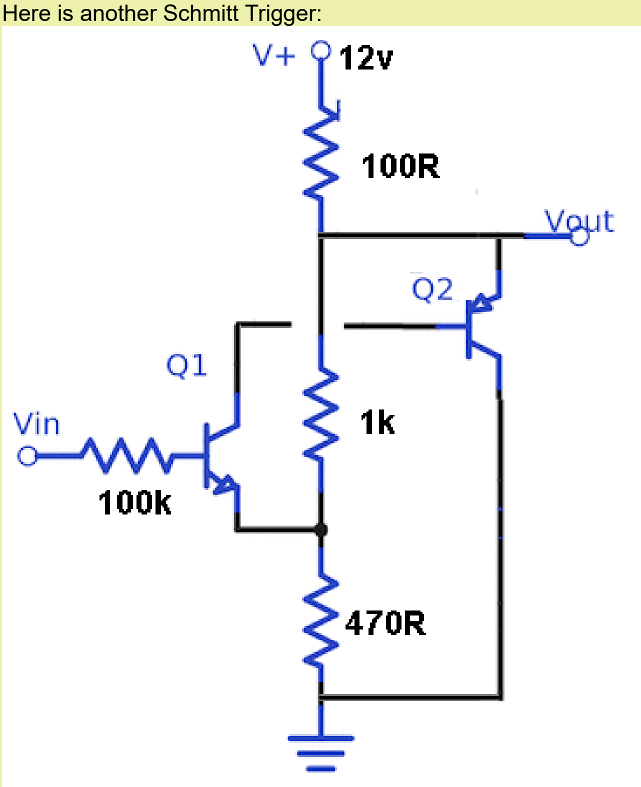


Fig 79aa. A Schmitt Trigger

Fig 79aa is a Schmitt Trigger made from NPN and PNP transistors.
As the voltage on the input rises, the first transistor is turned on slightly and a small voltage is developed across the 100k emitter resistor that reduces the "turn-on" effect slightly. This means the input voltage must rise more. As the input voltage rises more, the second transistor starts to turn on and the collector voltage rises. This voltage is passed to the base of the first transistor to assist the input voltage and because the collector voltage of the output transistor rises considerably, it has a large effect on turning ON the first transistor. They turn each other ON until they are both fully turned ON.

The 2M2 has taken over from the 470k and made the base of the input transistor slightly higher. The input voltage has to drop a small amount before the pair will start to turn off.
The circuit has created a small gap between the low and high input voltage (and between the HIGH and LOW input voltages) where the circuit does not change from one state to the other. This gap is called the **HYSTERESIS GAP**.
The output of the Schmitt Trigger in **Fig 79aa** is classified as "high impedance" (due to the value of the 100k on the output) and this must be connected to a stage with a high input impedance so the voltage on the output of the Schmitt Trigger is not affected.

Here is another Schmitt Trigger:



The only problem with this circuit is the load is not pulled very close to the 0v rail. The minimum voltage across the PNP transistor is about 1.5v, however the circuit works well and provides a wide voltage between ON and OFF. It has been tested with a load of about 30mA across the 100R.
Changing the 470R to 1k increases the "gap."

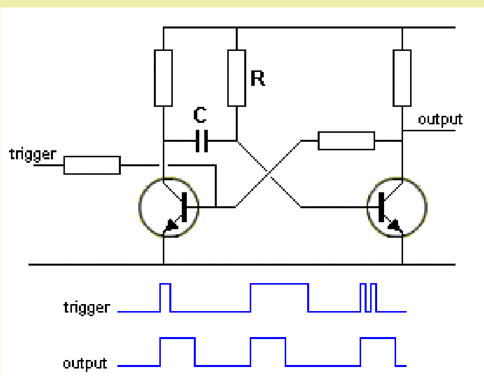


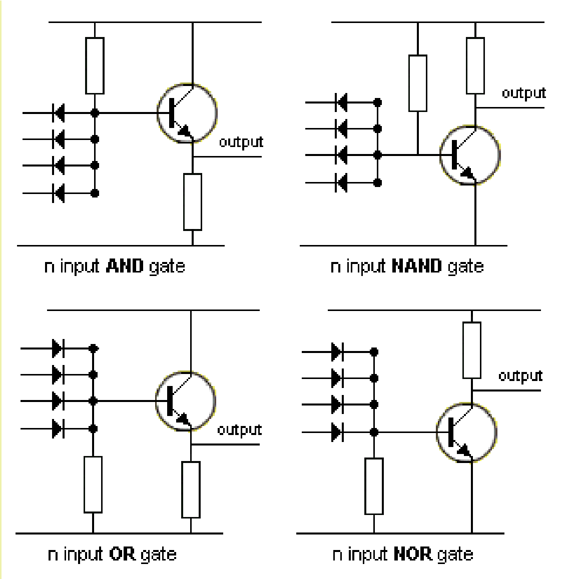
Fig 79ab. The Monostable or "Pulse Extender."

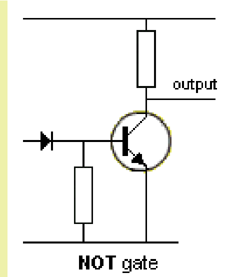
Fig 79ab. Before we leave the MULTIVIBRATOR family, the third type of Multivibrator is the **MONOSTABLE MULTIVIBRATOR**.
It is only stable in **ONE** state. This is called the "rest" state. The other state is "timed" via a capacitor.
The circuit is triggered and it changes to the other stage and a TIMING CAPACITOR **C** charges via a resistor **R** (called a TIMING CIRCUIT) and a multiplication of the two produces a value called the **time constant.** When it is charged, the circuit drops back to the rest state.
While the output is high, input pulses (trigger pulses) have no effect on the circuit. Also, if the input is triggered and kept high longer than the **time constant** of **C** and **R**, the output will NOT stay high for longer than the **time constant**.
This circuit is also called a **PULSE EXTENDER**.

GATES

We have described the transistor as an amplifier and the fact that **POSITIVE FEEDBACK** can turn a transistor **ON** more and more, so it changes from: "**not-turned-ON**" to "**fully-turned-ON"** in a very short period of time. When a transistor is operating in this mode, it is said to be in **DIGITAL MODE.** We saw the effects of **DIGITAL MODE** in Figs 74, 75, 76, 77 and 78. The advantage of **digital mode** is the transistor dissipates the least heat in either state.
The transistor can be put into a chip (IC - Integrated Circuit) and used in Digital Mode. When this is done, the transistor is put into a circuit called a **GATE. A Gate** is simply a **BUILDING BLOCK** in which the output changes from **LOW** to **HIGH** or **HIGH** to **LOW** very quickly. The simplest **GATES** are called AND, OR, NAND, NOR and NOT. In general a GATE operates on a 5v supply (this applies to gates in the TTL family. They cannot withstand a voltage higher than 5.5v. CMOS gates operate to about 14v-16v and some are up to 20v) and the input has to change from **LOW** to **HIGH** or **HIGH** to **LOW** very quickly and the output will change from **LOW** to **HIGH** or **HIGH** to **LOW** very quickly. You may think the gate is not achieving anything, but most gates have 2 or more inputs and the output is "more powerful" than the input. The introduction of GATES revolutionised the development of the computer and was the beginning of the **DIGITAL AGE.**

Fig 79ac shows AND, OR, NAND, NOR and NOT gates produced with transistors.





"n" indicates any number of inputs. ("n" is an unspecified number.)

Fig 79ac.

We have shown circuits with the load (such as a speaker or LED) above the transistor or below (it cannot be in both places at the same time). The position of the LOAD introduces two new terms:

SINKING AND SOURCING

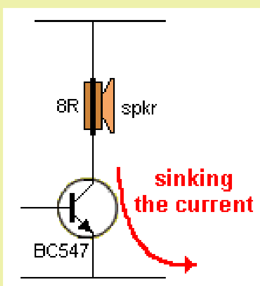


Fig 79b.

Fig 79b. When the speaker (LOAD) is placed above the transistor, the circuit is said to be **SINKING** the current. A BC547 does not have the collector-current to adequately supply an 8R speaker. You really need a BC338.

There is no advantage in one placement over the other. If the load is connected to "chassis" such as a globe in a car, the circuit will need to source the current.

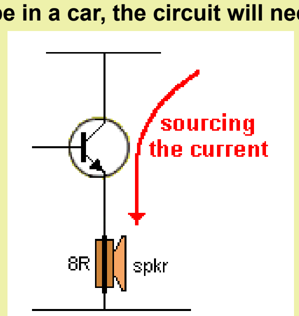


Fig 79c.

Fig 79c. When the speaker (LOAD) is below the transistor, the circuit is said to be **SOURCING** the current.

The only difference between the two circuits is the voltage on the base. Fig 79b will operate with a base-voltage less than 1v, while Fig 79c is an emitter-follower design and will need a voltage on the base from about 1v to full rail voltage.

INTERFACING

Interfacing simply means: "connecting." When a circuit connects a device (such as a microphone), to an amplifier, it is called **INTERFACING**. The characteristics of the microphone are matched to the input requirements of the amplifier. Or a relay may need to be connected to the output of an amplifier (If the amplifier does not have enough current to turn the relay ON).
In most cases, the output of a circuit or a "pick-up" device (sometimes called a TRANSDUCER) does not have enough VOLTAGE or VOLTAGE-SWING or AMPLITUDE to drive the next circuit or device and it needs an amplifier.
That's why we have to add a circuit between.
The circuit we add has a number of names:
When it increases the CURRENT, we call it a **BUFFER**.
When it matches a high impedance to a low impedance or a low impedance to a high impedance, we call it **IMPEDANCE MATCHING**.
Or when we need an increase in voltage, it is called an **AMPLIFIER**.
In ALL "stages" (common-base, common-collector and common-emitter) the current is increased.
Interfacing can be as simple as adding a resistor or capacitor, but this is usually called "connecting" or

"coupling".

We have learnt that all devices and circuits have an ability to deliver a "waveform" or "amplitude" or "voltage" and this can be weak or strong according to the amount of current it can deliver.
We have also learnt that this current may be delivered from the load resistor or from the device itself. It does not matter how the current is delivered; the **size** of the current (the amount of current) is important.

We have also covered the fact that the input to a circuit (or "stage") requires current and when these two are equal, the matching is ideal.
But this rarely happens.
If the input requires **more** current, the voltage (or voltage-swing) from the previous circuit or device will be reduced. If the input requires less current, the voltage-swing will be affected a very small amount. But in **ALL** cases the voltage-swing will be reduced - because you ARE supplying SOME energy to the stage that follows.

Interfacing is not easy.
You have to know the **output voltage** of the device and the **current** it can supply.
The current it can supply is related to its **OUTPUT IMPEDANCE**.
OUTPUT IMPEDANCE basically means its output resistance. A low resistance or LOW IMPEDANCE means it is capable of delivering a HIGH CURRENT. A high-impedance device cannot deliver very much current. A stage with a high output impedance cannot deliver very much current.
All these terms are relative. When we say: "cannot deliver much current" the value of current can be less than 1uA or 50mA. It depends on the circuit we are discussing and if you are working with low-current circuits or power circuits.
We have also learnt that the input impedance of a stage can be high or low and the voltage-swing it will accept can be small or large. (for instance, an emitter follower stage will accept a large input voltage).
This gives us a wide range of values (parameters) that may need to be joined together - **INTERFACED**.
In some cases the output voltage of a device or circuit will be HIGH and by connecting a capacitor between the two stages, the output voltage will be "absorbed" in the capacitor and the energy from the output stage will be transferred. The "energy" is a combination of the voltage-swing and the current.
But if the output voltage is very small, we may need to amplify it to deliver a high voltage to a device.

This is the case in the following requirement.
A piezo diaphragm or electret microphone is required to be interfaced to the input of a microcontroller.
The output of these devices is about 10mV and the input of a microcontroller requires about 3.5v (3,500mV).
This involves an amplification (gain, amplification factor) of 10:3500 = 350 and requires two stages of amplification.
The output of a piezo and microphone are classified as high impedance and the input of a microntroller is also high impedance.
This means the two amplifying stages can be low-current stages (also called high-impedance stages) and the load resistors can be high-value (about 22k - 100k).
The following two circuits have been designed for this application:

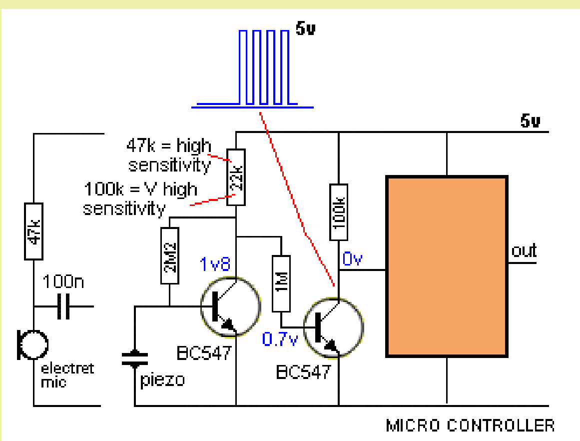


Fig 79d.

Fig 79d. In this circuit the first transistor is self-biased and the 2M2 base bias resistor turns the transistor ON and the voltage on the collector is only about 1.8v.
This means the collector has to drop by only 1.2v for the second transistor to turn off and the 100k will produce 5v on the input to the microcontroller.
If the transistor has a gain of 100, the electret mic or piezo has to produce a 12mV signal to activate the circuit.
When the load resistor is increased to 100k, the collector has about 850mV on it, and it only has to drop 300mV for the signal to enter the microcontroller. This makes the 100k load resistor produce a more-sensitive circuit. When no audio is being detected, the output of the second stage is 0v.

Fig 79e. This circuit has been taken from Fig 71acc. It is a bootstrap circuit and produces a very clever "switch."
The circuit sits with the first transistor turned ON and the second turned OFF as can be seen in the first line at the top of the output waveform - up to the red dot. When a signal is picked up by the microphone (this is the red dot on the waveform), a negative-going signal of about 100mV will turn the transistor off slightly and the second transistor will turn ON. The 4u7 will be "pulled down" and

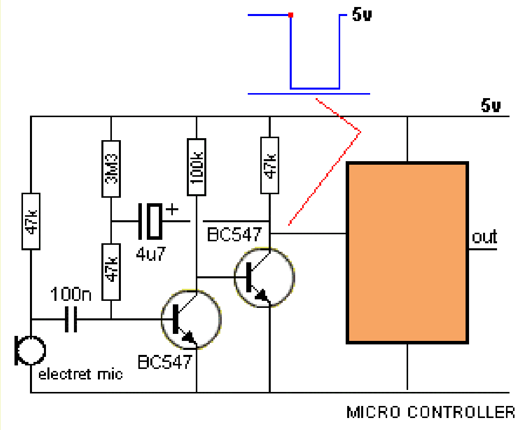


Fig 79e.

completely take over from the signal from the microphone. It will turn the first transistor off more and the second transistor will be turned ON more. This will continue until both have completely changed states.

They will stay like this until the 4u7 is charged in the opposite direction and the base of the first transistor sees 0.7v. This causes the second transistor to turn off and the 4u7 rises and turns the first transistor ON more. The 4u7 gets slowly discharged and the circuit remains in this state.
The circuit produces a very clean output every time it detects audio.
The duration of the low in the graph can be shortened by reducing the value of the electrolytic.

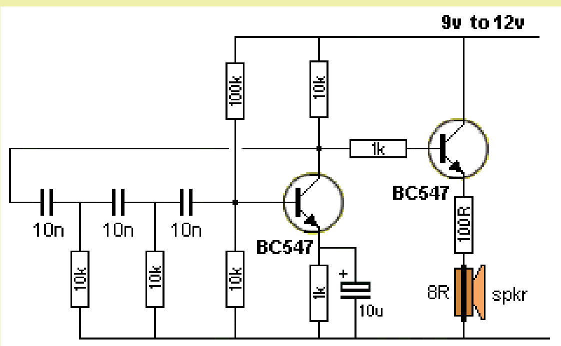


Fig 79f

Fig 79f interfaces a phase-shift oscillator (see **Fig 90**) to a speaker. This is a very difficult thing to do as the phase-shift oscillator has an output that is very close to rail-to-rail and any loading of the output will cause it to stop working.
In an attempt to interface the oscillator to a speaker we have added an emitter follower transistor and a 1k separating resistor, plus a 100R in series with the speaker. This should give a loading of about 20k and the circuit should work. Otherwise the 10k will have to be reduced or the 100R increased.

ANALOG TO DIGITAL

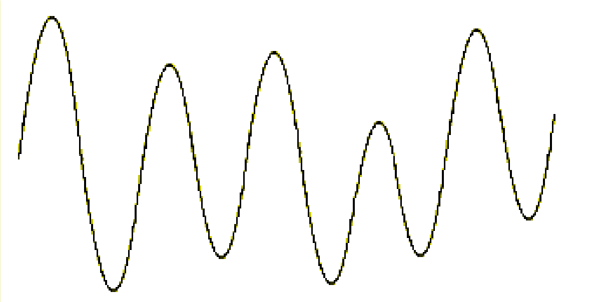
Many of the circuits we have described convert an **ANALOG** signal to a **DIGITAL** signal.
These are called **ANALOG TO DIGITAL CONVERTERS** but we have not given them this specific name because we have been concentrating on other features.
We will now cover the concept of **Analogue to Digital Conversion**.
An ANALOGUE signal rises and falls but doesn't have any defined amplitude or frequency.
This signal cannot be delivered reliably to a circuit that requires a DIGITAL SIGNAL as the amplitude may not be large enough.
A **DIGITAL CIRCUIT** requires a **digital signal** and this type of signal is either a constant HIGH or LOW and the amplitude must be very close to rail voltage or almost 0v. And it must change from one state to the other **very quickly**.
Delivering a high amplitude analogue signal **may** be recognised by a digital circuit when it reaches a peak or goes to 0v, but this is not guaranteed or reliable.
In addition we may want the signal to be a CONSTANT HIGH when the audio is present.
This is what an **ANALOG TO DIGITAL** circuit will do. It will produce a constant HIGH when audio is present and ZERO (LOW) when the audio is not present. Or pulses that are nearly rail voltage and very close the 0v.

Recapping:
To convert an analogue signal to a digital signal we need to deliver ZERO OUTPUT (called a LOW output) when the signal has a small amplitude and a HIGH output when the signal has a high amplitude.
To do this we use a common-emitter stage, as it has a high voltage-gain and this is what we need.

There are many ways to convert an **Analogue signal** to a **Digital signal** but the basic way is to amplify the signal by a large amplification-factor so the resulting waveform will rise to the voltage of the rail (or even higher). It cannot go higher than rail voltage but you will see what we mean in a moment.
This is normally called "over-driving" the signal and if this is done in an audio circuit, the result is distortion. But we are not going to listen to the output, so we take advantage of this feature to produce a DIGITAL OUTPUT.

Fig 80a shows an analogue signal. It is made up of lots of sine-waves and may be as high as 2v or only a few millivolts. Low-level signals are generally expressed in

mV, to make them instantly recognisable and easy to talk about. In general this type of signal will be too small to be detected by a Digital Circuit. A Digital Circuit needs a signal greater than about 3,500mV so the waveform appears on the input line as a HIGH, during the peak of its excursion. It should be nearly 5,000mV for reliable detection.



A VARYING Analogue waveform

Fig 80a

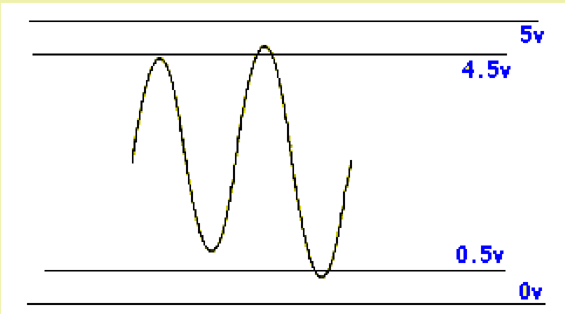
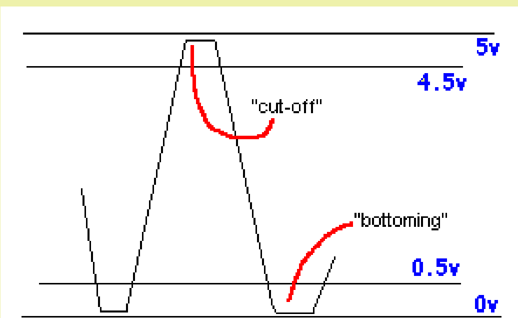


Fig 80b. A Digital Circuit will detect a waveform larger than 4.5v as a HIGH and less than 0.5v as a LOW

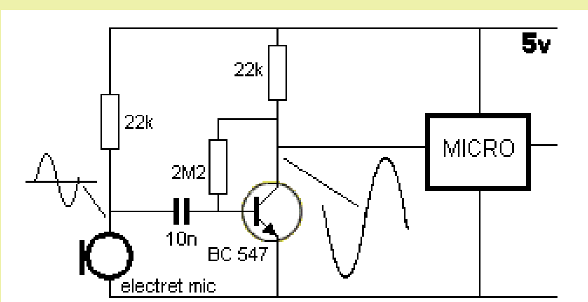
Fig 80b. Only the large excursion(s) will be detected by a Digital circuit as the other parts will not rise high enough to be detected. To increase the analogue signal to as much as 5,000mV, an amplifier is needed.



An "over-amplified" waveform will be cut-off at the top and bottom.

Fig 80c.

The amplifier maybe one or two stages, depending on the amplitude of the original signal.
Each stage of an amplifier will increase the size of the signal about 70 times. If you are very lucky, you may get an amplification of 100x (100 times).
Thus a 5mV signal with one stage of amplification will produce a 350mV to 500mV signal. This is not sufficient to be detected by a Digital Stage.
Another stage will easily produce a full 5,000mV signal.
The second stage only needs to amplify the signal about 10 to 12 times and a higher gain simply drives the waveform into "**bottoming**" and "**cut-off**" as shown in **fig 80c**.



The waveform of a whistle.

Fig 80d.

This means the waveform will be "clipped" at the top and bottom and converted to a fairly "square-ish" shape.
Suppose you have a waveform that is higher than 5mV (say 30 - 50mV) and want to know if it will trigger a Digital Circuit with a single stage of amplification.
Connect the components as shown in **Fig 80d** and write a program to illuminate a LED when the waveform is detected.

There is only one problem with the circuit in Fig 80d.
At the end of a whistle or speech, the LED may be illuminated or extinguished. It all depends on the last cycle of the waveform. The circuit sits with the output approx mid-rail and the micro does not know if this is a high or low, and takes the reading by the direction of the last cycle.
Some of the inputs of a micro are Schmitt Triggered. This means a HIGH has to be 85% to 100% of rail voltage for it to be seen as a HIGH and between 20% and 0% to be seen as a LOW.
The non-Schmitt Trigger inputs see a LOW as 20% to 0% and a HIGH as above 2v for 5v operation.
If the last cycle went from zero to mid-rail the micro will see the waveform as a low on Schmitt Trigger inputs and a HIGH on the other inputs. This problem can be overcome by adding a second stage that only produces a LOW when audio is detected. It also increases the amplitude of the audio to guarantee triggering of the Digital Circuit. This is shown in **Fig 80e**.

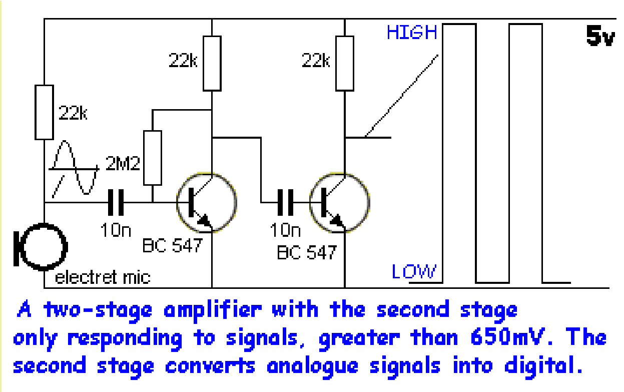


Fig 80e.

The second transistor in **Fig 80e** is called a DIGITAL STAGE. This simply means a biasing resistor is not connected to the base of the second transistor so it turns on fully when a signal greater than 650mV is detected and is turned off at other times. This stage is ideal for a micro or other Digital Stage as only two voltage levels are delivered. Either 0v or rail voltage (5v).The other advantage is it does not take any quiescent (idle) current.
This stage is only suitable if you are sure you have plenty of "over-voltage" to drive the transistor into saturation. By this we mean you must have at least 1v (1,000mV) drive signal so you can be sure the transistor will turn on (saturate).
The fast rise and fall times means you have a "clean" HIGH and LOW.

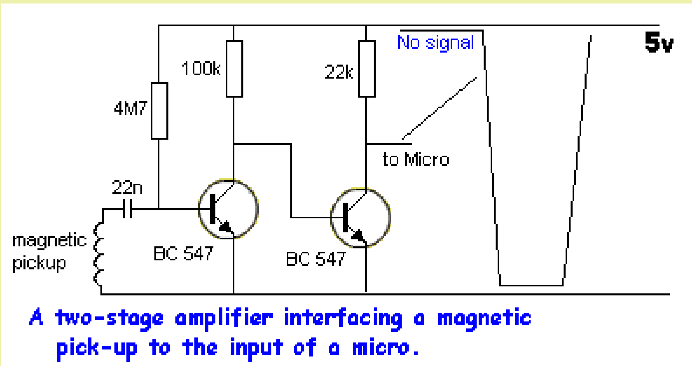


Fig 80f.

Fig 80f couples a magnetic pick-up to the amplifying circuit so the biasing of the first transistor can be determined by the value of the base-bias resistor. The coil cannot be connected directly to the transistor as the low impedance (resistance) of the coil will upset the bias on the base.

With this arrangement, the descending part of the input waveform of a few millivolts will turn off the transistor, while the ascending part of the waveform will not have any effect.
A coil of wire of any size will be suitable and to make it an effective collector of magnetic flux, it should have a magnetic core such as ferrite. No other impedance-matching is necessary.

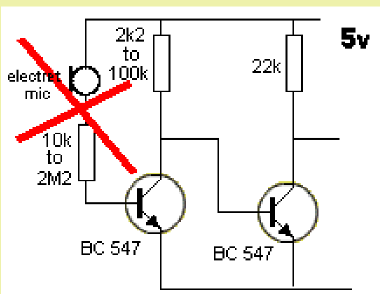


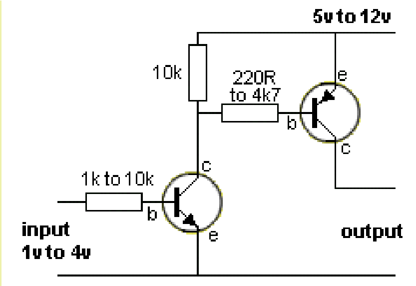
Fig 80g.

Fig 80g shows an electret microphone connected directly to the base of a two-transistor amplifier. This arrangement will work and provides the best transfer of signal from the microphone to the base.
But biasing the first transistor is a very difficult thing to do. The electret microphone needs a very small current to operate and the series resistor allows this current to flow.
You will need to build the circuit, select values for the base and collector then whistle into the microphone to see which combination produces the highest gain.
If the resistor is a small value, the base current will be high and the transistor will be turned on fairly hard. This is called BOTTOMING and the collector voltage will be very low.

The electret microphone will produce a signal and this will increase and decrease the current into the base. But the reduced current will no turn the transistor off any appreciable amount and the signal will not appear on the collector. If the base resistor is very high, the electret microphone will not produce a very large output signal and again, the waveform on the collector will be very small.
There is no way anyone can predict the best values to use. It depends on the type of microphone, the gain of the transistor and the rail voltage. This is a very messy design and should be avoided. It has been included because it has been seen in circuits on the web.

LEVEL CONVERSION or LEVEL SHIFTING

Suppose the output of a device is 3v and you want to activate a device that requires 5v or 12v.
This circuit converts the signal that rises from about 0v to about 4v to a signal that rises from 0v to 5v or 12v.

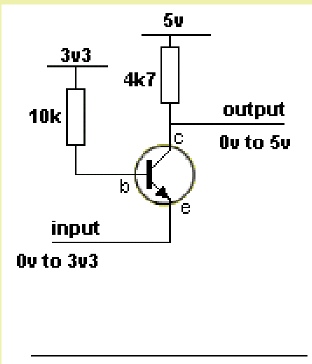


LEVEL CONVERSION

Note: The output is not inverted, it is in-phase with the input due to two inversions within the circuit.
The resistor values and the type if transistor will depend on the output current required.

3v3 to 5v:

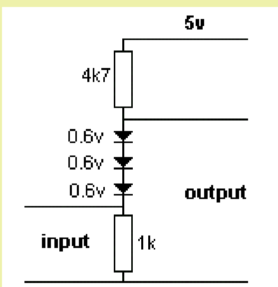
When we talk about **LEVEL CONVERSION** we are only interested in **TWO STATES**. The zero state or LOW LEVEL and 3v3 (or 5v) or HIGH STATE (high level).
This circuit produces and output of 0v when the input is 0v and 5v output when the input is 3v3.
The circuit is not linear throughout the whole transition but that is not important for a DIGITAL to DIGITAL transfer. It is only the HIGH or LOW condition that is important.



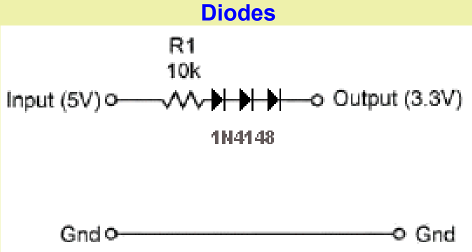
3v3 to 5v

3v3 to 5v with diodes:

Level conversion can be done with 3 diodes to change 3.3v to about 5v, but you have to know the current-capability of the 3.3v source and the current requirement of the 5v section. This arrangement is only suitable for very small current requirements.
The output is allowed to be taken HIGH by the input providing 3.3v and the 3 diodes providing 2.1v. This allows the 4k7 to pull HIGH with a very small current-capability.



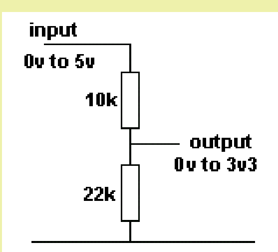
LEVEL CONVERSION with Diodes



The 10k resistor is only a safety resistor and can be removed when the two sections are working correctly. When the 5v line is 0v, the output is 0v. When the 5v line is 5v, the output is about 3.2v.

5v to 3v3:

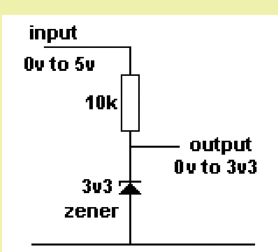
A 5v signal can be converted to 3v3 with two resistors called a **VOLTAGE DIVIDER**.
This circuit will work with both analogue and digital signals.



LEVEL CONVERSION with Resistors

5v to 3v3:

A 5v signal can be converted to 3v3 with a 3v3 zener.



See also LEVEL CONVERSION using an Inverter

LEVEL CONVERSION with a Zener

OSCILLATORS

There are over 20 different types of oscillators and many more variations. We cannot cover them all - so we will concentrate on the most often-used and explain how they work.

Oscillators consist of one or two transistors. They start-up by one or more components in the circuit producing "noise" or a spike from the "mains" when the circuit is turned on. Some oscillators will not start-up if the supply is increased gradually. When a spike or noise is detected, the rest of the circuit amplifies it. In most cases the noise comes from the circuit being turned ON but it can also come from the noise generated within the junction of a transistor. This noise is random and of little use, but it is fed to components such as coils and capacitors as they have the ability to produce a waveform that rises and falls smoothly and this is amplified to produce the output.
When coils, crystals, capacitors and resistor are combined with transistors, many different effects and waveforms can be created and this all comes under the heading of OSCILLATORS. And the circuits are all amplifiers.
An amplifier can be turned into an oscillator by providing POSITIVE FEEDBACK.
The purpose of providing **NEGATIVE FEEDBACK** is to prevent oscillation.
The purpose of providing **POSITIVE FEEDBACK** is to create oscillation.
Positive feedback is when you take a point that is rising a **large amount** and pass it to a point that is also rising at the same time but only a **small amount**.
In other words, the feedback line must be able to **help** or **assist** the small-signal line. If it does not **assist** the small-signal line, NO oscillation will occur.
Some oscillators have a name - either after their inventor, by the way they are configured or by the shape of the wave. Some have 5 names. **Some have no particular name and are just called Feedback Oscillators (positive feedback).**

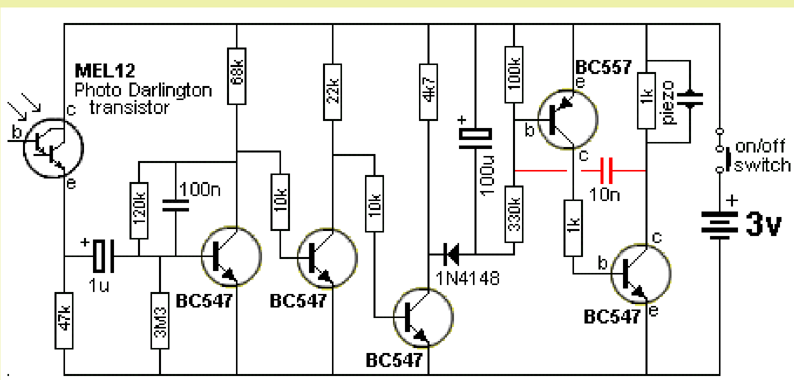


Fig 80. The 10n capacitor provides the positive feedback to keep the circuit oscillating.

Fig 80. A Feedback Oscillator

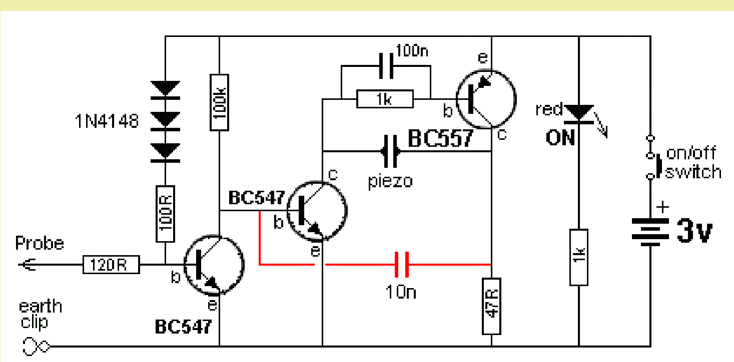


Fig 81. The 10n capacitor provides the positive feedback to keep the circuit oscillating.

Fig 81. A feedback oscillator

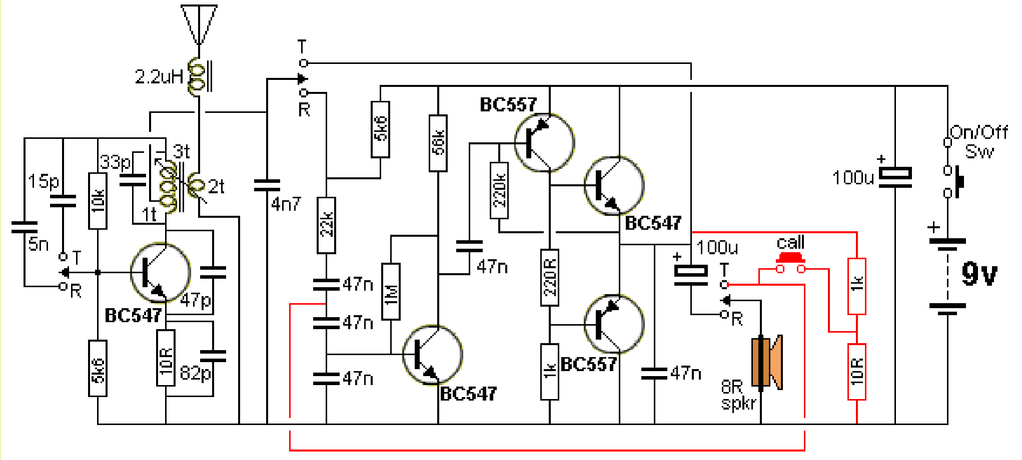


Fig 82. The positive feedback line creates the CALL tone

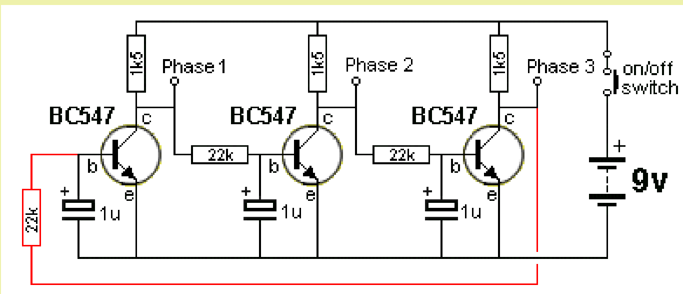


Fig 83.

Fig 83. When the third transistor is turning OFF, the collector voltage is rising and this is passed to the base of the first transistor, to turn it ON.
This is how the circuit keeps "cycling" or oscillating.

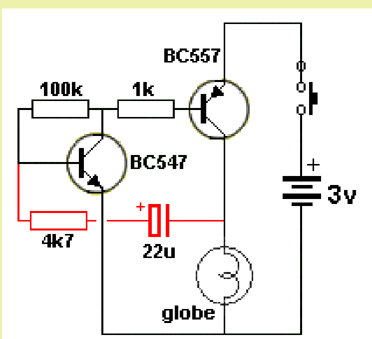


Fig 83a. Globe flashes at 1Hz

Fig 83a. The high-gain amplifier we studied in Fig 66, for example, has negative feedback to prevent oscillation. By using positive feedback we can turn the high-gain amplifier into an oscillator.
This circuit is simply a high-gain amplifier with both transistors turning ON via the 1k and 100k resistors. This makes the voltage on the collector of the BC557 rise and the 22u and 4k7 passes this rise to the base of the BC547 to turn both transistors ON more and more until they are fully turned ON.
The 22u charges a little more and this reduces the current into the base of the BC547 to turn it off a little. This effect is passed to the collector of the BC557 and the two transistors start to turn OFF. When they are fully turned off, the cycle repeats by the transistors being turned on via the 1k and 100k.

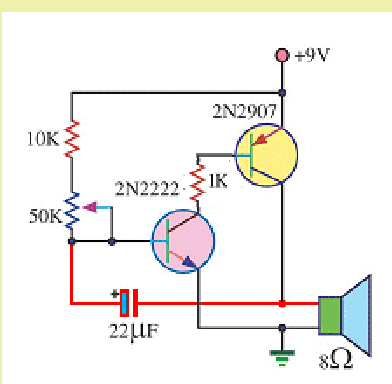


Fig 83aa. Simple Tone Oscillator

The 2-transistor amplifier we studied in Fig 42 can be changed slightly to drive a speaker. The two common-emitter transistors turn on together and the 22u is "lifted" to turn on the NPN transistor harder.
Both transistors turn on until fully saturated and this puts current though the speaker.
The 22u charges a little more and this reduces the current into the base of the NPN transistors, turning it off a slight amount. The PNP is turned off a small amount and they both keep turning off until fully turned off.
The 10k and 50k start to charge the 22u to repeat the cycle. The 22u produces positive feedback. It can be replaced by values from 100n to 22u to change the frequency of the tone.

The two circuits above are examples of **LOW IMPEDANCE** outputs. If the load (the globe or speaker) is increased above about 47 ohms, the circuit will not work. They simply "lock-ON." This is because the capacitor (electrolytic) must be pulled down by the load at a very critical point in the cycle. In addition, the 100k "turn-on" (or 50k and pot) resistor must be a very high value. If it is too low, the circuits will "lock-ON."

The critical point is this: When the circuit is fully turned-ON, the right side of the capacitor is near rail voltage and it is being charged via the bas-emitter junction of the first transistor. As it becomes fully charged, the current into the base of the first transistor reduces slightly and the transistor turns off slightly. This effect is passed to the second transistor and it turns off slightly too. The right lead of the capacitor drops and this lowers the left lead to turn off the first transistor slightly more. This is the beginning of the "turn-off section" of the cycle.
If the second transistor did not have a very heavy load (low resistance load), the slight turning-off of the two transistors would not lower the capacitor and they would both remain ON.

also called the PHASE-SHIFT OSCILLATOR

A Sine-wave Oscillator can be made with a single transistor.

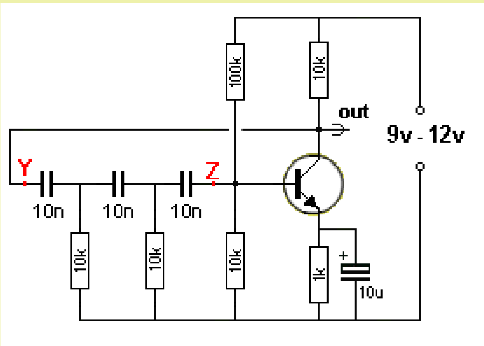


Fig 90. The Sinewave Oscillator

Fig 90. This circuit produces a sinewave very nearly equal to rail voltage.
The important feature is the need for the emitter resistor and 10u bypass electrolytic. It is a most-important feature of the circuit. It provides reliable start-up and guaranteed operation. For 6v operation, the 100k is reduced to 47k.
The three 10n capacitors and two 10k resistors (actually 3) determine the frequency of operation (700Hz).
The 100k and 10k base-bias resistors can be replaced with 2M2 between base and collector.
This type of circuit can be designed to operate from about 10Hz to about 200kHz.

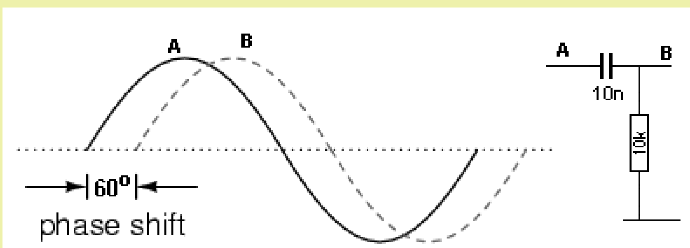


Fig 91.

Fig 91. The phase-shift oscillator has 3 "sections" made up of a 10n capacitor and 10k resistor. This "section" is shown above and each "section" produces a delay or "phase-shift" of about 60° but the total must be 180°. The base and collector of a common-emitter stage are 180° out-of-phase, so the signal entering the base is 360° (IN-PHASE with the output). This creates POSITIVE FEEDBACK.
This concept is very hard to understand so we need to explain it in simple terms.
Points Y and Z are the ends of a long piece of rope and the three resistors are weights tied to the rope. You shake the rope up and down at Y and Z moves up and down at a later time in the cycle. You know this because you can make a wave travel down a rope. Exactly the same thing happens with a signal that enters at Y. It takes time for the peak to reach Z.
Now consider the circuit at switch-on. The caps are uncharged and the 10k collector resistor pulls the three capacitors high. Taking into account the voltage-dividing effect of the three lower 10k resistors, the collector is possibly at about 2v. The three 10k resistors start to charge the three 10n caps and the voltage on the base falls. This makes the collector voltage rise. This continues until the collector cannot rise any further and the capacitors continue to charge and the voltage on the base drops. The 100k base resistor takes over and starts to discharge the 3rd capacitor and turn the circuit on. The collector voltage drops and the energy in the three capacitors get passed into the base to fully turn the transistor ON.
This all happens in a "sliding motion" that produces a sweeping output called a SINEWAVE. It is a very "delicate" oscillator and any change to the LOAD (10k) may stop its oscillation.

How to read the Graph: Get a ruler and hold it "up and down" on the page (or on the screen) so you view the right-hand edge of the ruler and can only see the word "phase" and "60° " Now slide the ruler to the right and you will see the graph "A" gradually rising. Keep moving the ruler to the right and you will see graph "B" gradually rising.
This is how you "interpret" the graph and see how graph "B" lags (is behind) graph "A." If you don't read the graph correctly, it looks like graph "B" is in front of graph "A" - but this is not the case.

HOW THE CIRCUIT WORKS

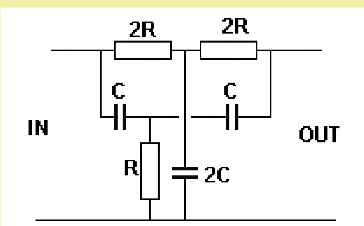
When the power is applied to the circuit the transistor will immediately turn on FULLY as the three 10n capacitors will acts as "short-circuits" and current will pass to the base and the collector voltage will fall to a very LOW level.
The capacitors will gradually charge via the 10k resistors and the voltage across the second 10k resistor will drop (due to the charging current into the middle 10n gradually reducing) and the voltage on the left lead of the 3rd 10n will drop. This will reduce the voltage on the right lead of the 10n and turn the transistor OFF. The first two 10n's will start to charge but the voltage across the 2nd 10k will be very small and the 3rd 10n will start to charge via the 100k resistor.

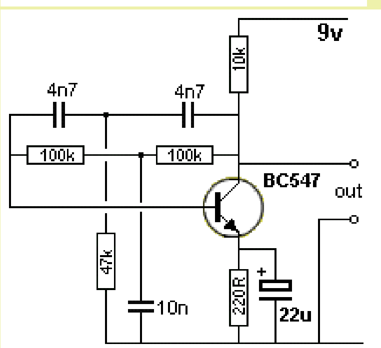
The charging of the first 10n is much faster than the charging of the third 10n and the voltage on the output rises to almost rail voltage. This allows the 3rd 10n to charge at a faster rate and just when the collector voltage reaches a maximum, the base voltage reaches 0.6v and the transistor starts to turn ON.
This lowers the collector voltage but the transistor still keeps turning ON via the 100k and the three 10n start to charge. This action increases the "turn-ON" of the transistor and it continues to turn-ON until the voltage on the collector reaches a very LOW level.
The circuit works completely differently to anything described in any Text Book. The transistor operates on a rising and falling CURRENT (increasing and decreasing current) into the base. That's why no-one has described it before.
The third 10n continues to charge and the "turn-ON" current for the transistor reduces and it starts to turn OFF a slight amount. The second 10k continues to charge the middle 10n and the voltage across the 10k reduces. This pulls the left lead of the third 10n towards the 0v rail and the right lead follows. This action turns OFF the transistor and the collector voltage rises.

REALITY

Once you see how the circuit **REALLY WORKS**, it has nothing to do with 60° phase shift for each section between **X** and **Y**. No-one has actually sat down and worked out how the circuit works and they just copy mistakes from others. The overall DELAY produces a signal that ASSISTS in keeping the circuit oscillating, but the feedback signal is not a simple sinewave.
It's possibly NOT important how the circuit works, but when you have trouble seeing how a 10n and 10k can produce a **60° phase shift,** you have to look into the circuit and satisfy yourself.
You cannot possibly expect to fault-find a circuit if you don't have an understanding of how it works. Things you will learn in one circuit can be applied to another circuit and this is how you progress. That's why the operation of this circuit ahs been provided and is completely different to anything that you would have considered.

THE TWIN-T OSCILLATOR





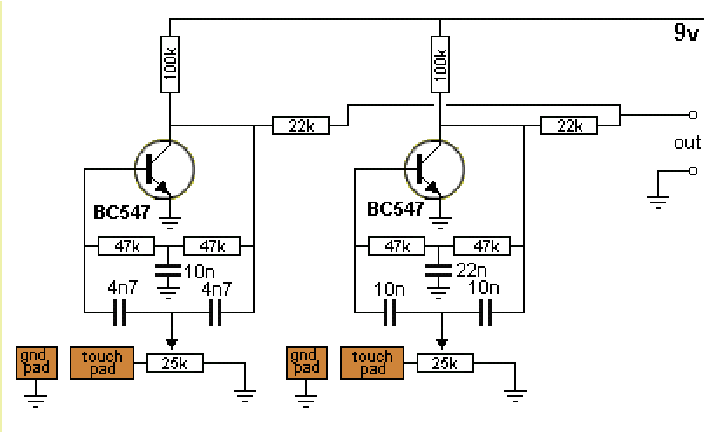
The basic twin "T" filter is a passive notch filter composed of two T-networks, with maximum attenuation occurring at

fnotch = 1/(2πRC)
One of these T networks has one resistor and two capacitors, while the other has two resistors and one capacitor. At the notch frequency fnotch of the twin-T filter, the total phase shift is zero, which satisfies the requirement for oscillation. This is why the circuit generates a sine wave with a frequency equal

to fnotch = 1/(2πRC).

Here's how the circuit works:
The transistor is turned ON because the base is connected to the collector via the two 100k resistors. But any signal (such as a voltage) coming from the collector will turn the transistor OFF. So a rising signal has to be delayed to arrive at the correct time to make the transistor oscillate.
There are two other factors that make the circuit work. The first is the 4n7, 47k and 4n7. Any frequency on the collector will pass through the two 4n7 capacitors and the 47k will be a "load." As the frequency on the collector increases, more of the signal will pass through the "T" network and appear on the base.
This means the top "T" network allows the high frequencies to pass to the base.
The 100k, 10n, 100k allows the low frequencies to pass to the base. This is because the "resistance" of the 10n becomes less for a high frequency and it acts a "load" to attenuate the signal.
We have two separate circuits and when the frequency at the collector increases, the lower circuit reduces the signal. When the frequency decreases, the top circuit does not pass the full amplitude.
There is a frequency where the amplitude of the feedback-signal is the greatest and this is the frequency at which the circuit operates.
Finally we have a situation where the "feedback signal" is delayed by 180° by the capacitor-resistor networks and this means it assists in making the transistor oscillate.
This circuit is not easy to design and is not a good performer. It will stop oscillating if the output signal is passed to a circuit that reduces the amplitude.
The **Phase-Shift Oscillator** is much more reliable.

The circuit below consists of two "twin-T" oscillators set to a point below oscillation. Touching a Touch Pad will set the circuit into oscillation.
Different effects are produced by touching the pads in different ways and a whole range of effects are available.
The two 25k pots are adjusted to a point just before oscillation.
A "drum roll" can be produced by shifting a finger rapidly across adjacent ground and drum pads



THE BLOCKING OSCILLATOR

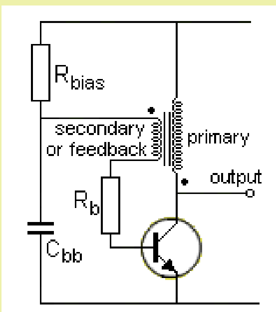


Fig 92.

Fig 92. The BLOCKING OSCILLATOR circuit uses a transformer to produce POSITIVE FEEDBACK to the base.
The circuit starts by Rbias charging Cbb to deliver voltage to the base of the transistor via Rb (and also a small current). The transistor turns on and produces expanding magnetic flux in the primary of the transformer. This flux cuts the turns of the secondary (or feedback) winding and increases the base voltage and CURRENT. The voltage out of the top of the secondary winding is prevented from "disappearing" by Cbb.
The transistor keeps turning ON until it cannot turn on any more. At this point, the current through the primary is a maximum but it is not expanding flux and its effect is not passed to the secondary winding. The base-current reduces enormously to the very small Rbias current and the transistor turns off abruptly (it takes a high base current to maintain a high collector current and the base current is very small). The heavy current through the primary is producing a very strong flux and it collapses, producing a voltage in both windings of opposite polarity and very high amplitude.

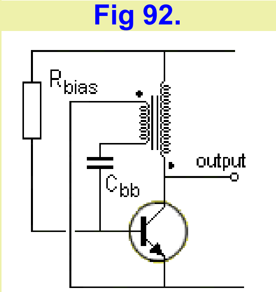


Fig 92a.

Fig 92a shows the base being "capacitor injected." This saves one resistor and can produce a higher output. All the values and the transformer needs adjusting for the performance required. The start of each winding is shown with a dot. This assumes the windings are wound in the same direction.

Figs 92b,c shows alternative ways to produce a blocking oscillator. The difficulty with producing a Blocking Oscillator is getting a suitable transformer.

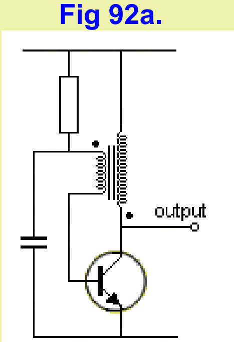


Fig 92b.

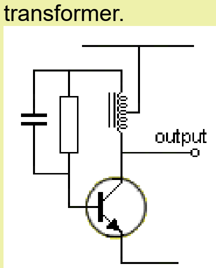


Fig 92c

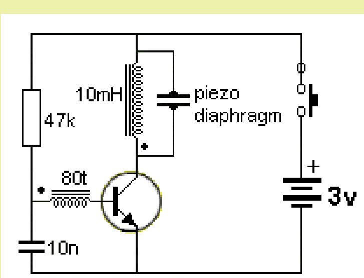


Fig 93.

Fig 93. A simple **BLOCKING OSCILLATOR** circuit can be made with a 10mH inductor and 80 turns of very fine wire wound on top.
The piezo diaphragm reacts to the very high "FLYBACK VOLTAGE" produced by the primary when the transistor turns off. This type of circuit is often used to produce very high voltages.

You can see the importance of FEEDBACK in a circuit. Some circuits will not work without feedback and some will distort. Sometimes the feedback is POSITIVE and sometimes NEGATIVE. The trick to understanding a circuit is to locate the feedback (component or "line") and work out what it is doing.

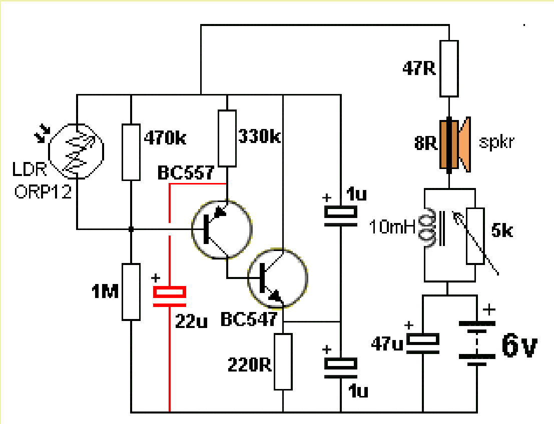


Fig 83b. Positive feedback comes from the 22u electrolytic.
This is a very unusual circuit.
Normally the feedback is obvious.

Fig 83b. Here's an oscillator circuit. We know it must have feedback to operate, but where is the feedback?
In this circuit the 4 electrolytics are equivalent to miniature rechargeable batteries.
When the circuit is turned on, they all get charged to a voltage according to the surrounding components but the 22u is the important component. The base of the BC557 sits at 4v and the emitter must rise to 4.6v for the PNP transistor to turn on.
When it does, it turns on the BC547 and this transistor puts a load of 220R across the circuit. This reduces the voltage across the 470k/1M voltage divider and the base if the BC557 sees a lower voltage. During this time the 22u is acting as a miniature supply and maintaining the voltage of 4.6v on the emitter.
The BC547 turns ON more and more and even though the voltage on the 22u drops, the circuit turns ON and this takes more current from the 6v battery and produces a click in the speaker.

THE SQUARE-WAVE OSCILLATOR

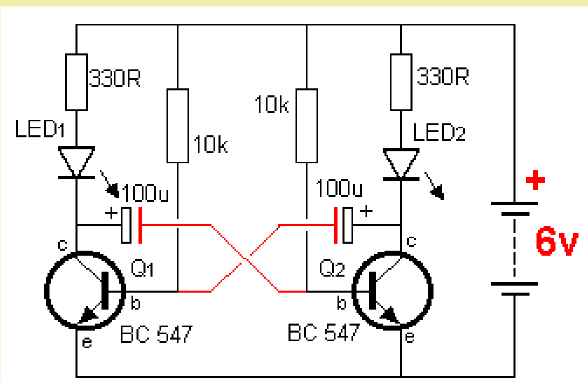


Fig 84.

When two transistors are cross-coupled as shown in **Fig 84**, you can safely assume the circuit will oscillate. The frequency of oscillation will depend on the value of the components but the oscillator is known as a **FREE-RUNNING OSCILLATOR** or **ASTABLE** (ay-stable) **MULTIVIBRATOR** and the output is a square wave. It will have an equal-mark-space ratio if the components are the same value.
This circuit is also called a **FLIP-FLOP**.

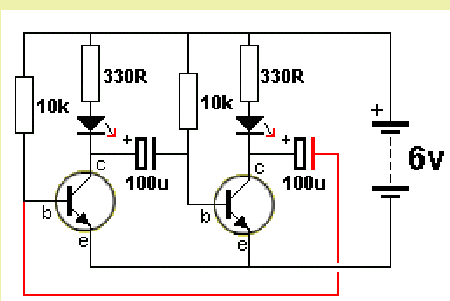


Fig 85.

Fig 85. By rearranging the components in Fig 84, we can draw the circuit as one common-emitter stage driving another common-emitter stage with a 100u providing positive feedback.
The circuit relies on the power being turned on quickly for it to start up. Both transistors will turn ON but one will turn on faster than the other and prevent the other turning on.
The 100u connected to the turned-on transistor will start to charge in the opposite direction and the second transistor will start to turn ON. This will pull the 100u lower and the first transistor will start to turn OFF. This will continue until both transistors have changed states.

Fig 86. Here is the **ASTABLE MULTIVIBRATOR** with the LEDs in the emitters instead of collectors (as is normal). The frequency of oscillation is approximately 1 second. The 330 ohm resistors set the LED current to 12mA for a 6v supply.

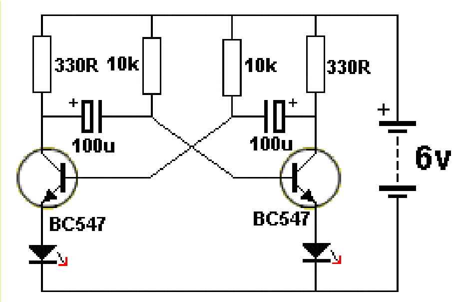


Fig 86.

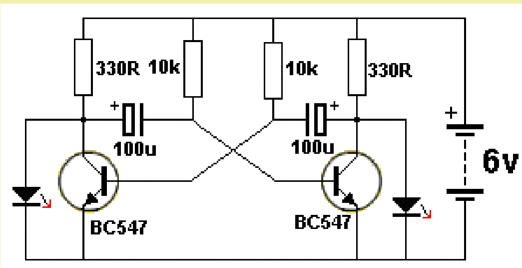


Fig 86a.

Fig 86a. The LEDs can also be connected as shown in this circuit. However the circuit takes more current than the previous designs. In the previous designs, one side of the circuit is taking current and illuminating the LED while the other side is turned OFF ("cut-off").
In Fig 86a, the "off" transistor is illuminating a LED while the "on" transistor is drawing current though a 330R resistor. Both sides are drawing current! This is a POOR DESIGN.

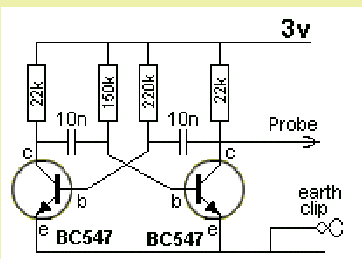


Fig 87.

Fig 87. The **ASTABLE** ("ay" - meaning not-stable) **MULTIVIBRATOR** circuit is rich in harmonics and is ideal for testing amplifier circuits. To find a fault in an amplifier, connect the earth clip to the 0v rail and move through each stage, starting at the speaker. An increase in volume should be heard at each preceding stage. This Injector will also go through the IF stages of radios and FM sound sections in TV's.

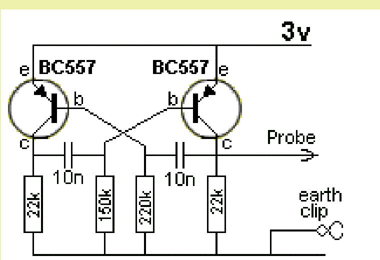


Fig 88.

Fig 88. The astable multivibrator can be made with PNP transistors.

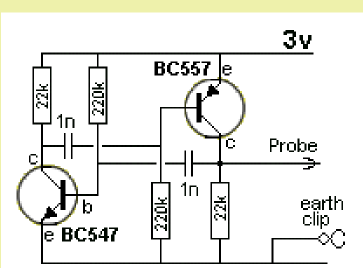


Fig 89.

Fig 89. A circuit can be made with one NPN and one PNP transistor. It ceases to be a FLIP FLOP or Multivibrator as both transistor turn on at the same time and the circuit becomes a **Relaxation Oscillator**.

THE SINE-WAVE OSCILLATOR -

Fig 94. This LED Torch circuit uses the "flyback" voltage of a BLOCKING OSCILLATOR to illuminate a 3.6v super-bright LED from a 1.5v supply.
Note: the 10n capacitor prevents the energy from the feedback winding being lost. All the energy from the feedback goes into the base of the transistor to turn it on hard.

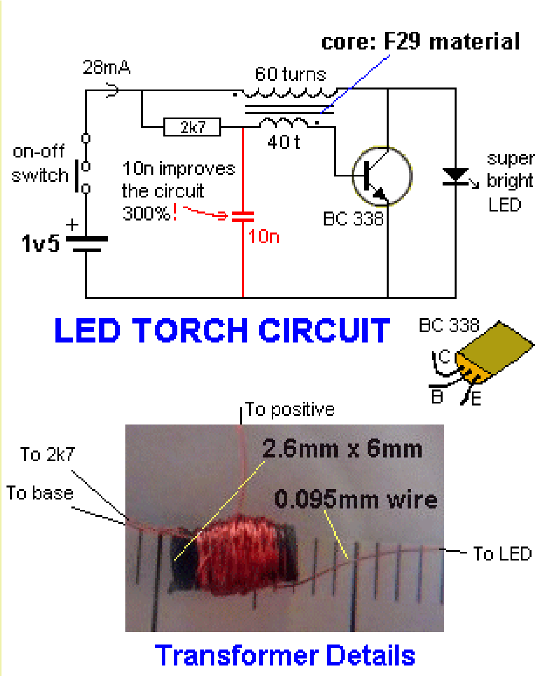


Fig 94.

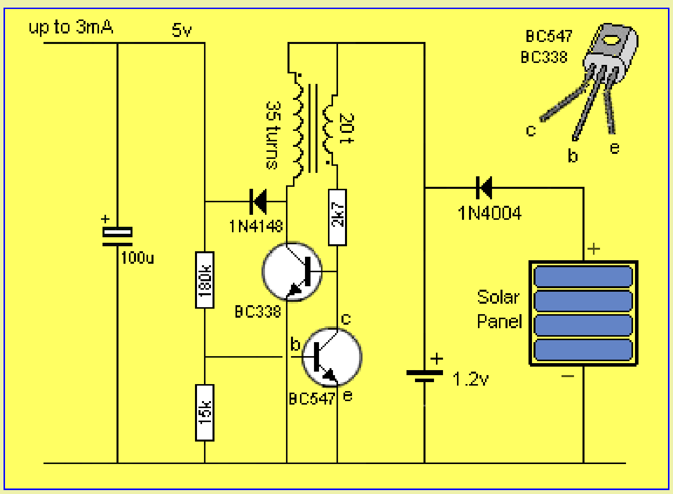


Fig 95.

Fig 95 shows a Blocking Oscillator producing a regulated 5v from a 1.2v supply.

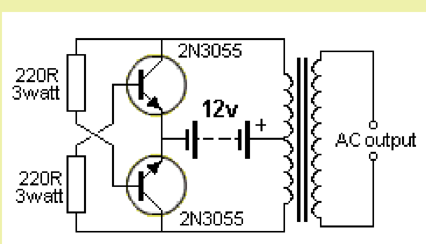


Fig 96. 2-transistors in PUSH-PULL - as a Blocking Oscillator circuit

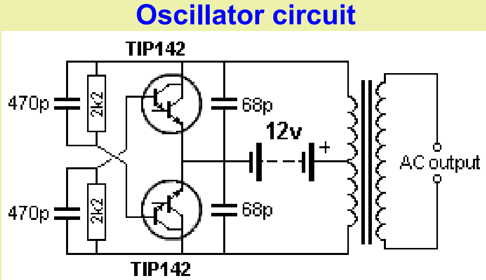


Fig 96a.

Fig 96. A simple extension of the Blocking Oscillator in Fig 92c above, is shown in this diagram. It consists of two **BLOCKING OSCILLATOR** transistors that are turning each other off. The circuit starts by one transistor being slightly faster than the other. It turns ON and produces magnetic flux that cuts the turns of the other half of the primary winding to increase the voltage from the battery and at the same time it reduces the voltage to the base of the other transistor - because the transistor allows only a very small voltage to appear across the collector-emitter terminals when it is turning ON. It keeps turning on until it is fully ON.
At this point the flux is no longer expanding and the generated voltage in the winding that supplies the base voltage (and current) ceases. This turns it off a small amount and the magnetic flux starts to collapse and produce voltages in the opposite direction. The voltage (and current) to the base is less than before and this turns the transistor off more. The voltage to the base of the other transistor starts to rise and that transistor takes over. The two transistors operate in PUSH-PULL mode.

To reduce the wasted power in the 220R resistors,

Fig 96a uses Darlington transistors and 2k2 0.5watt resistors. The circuit is used to drive a CFL lamp from a 12v battery.

The difficulty with producing a Blocking Oscillator is getting a suitable transformer. A similar "flyback voltage" can be obtained from an inductor. This will need an oscillator made up of two transistors to drive the inductor.

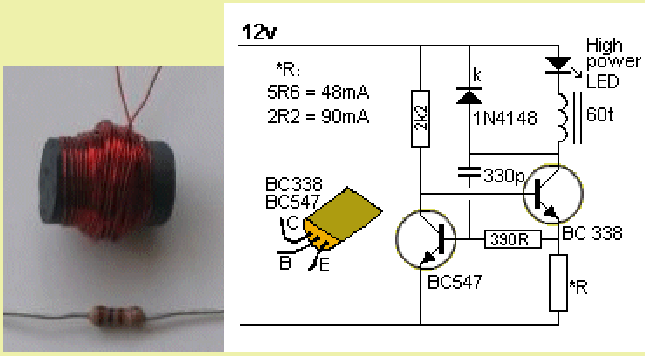


Fig 97.

Fig 97. This circuit is a "Buck Converter" meaning the supply is greater than the voltage of the LED. It will drive one high-power white LED from a 12v supply and is capable of delivering 48mA when R = 5R6 or 90mA when R = 2R2. The LED is much brighter when using this circuit, compared with a series resistor delivering the same current.
But changing R from 5R6 to 2R2 does not double the brightness. It only increases it a small amount.
The inductor consists of 60 turns of 0.25mm wire, on a 15mm length of ferrite rod, 10mm diameter.
Frequency of operation: approx 1MHz. This circuit draws the maximum current for a BC 338.
When the circuit is turned on the 330p gets charged. This turns on the BC547 and keeps the BC338 off. When the 330p is charged the BC547 is not turned on as much and the 2k2 can start to turn on the BC338. It pushes the charge on the 330p into the base of the BC547 to keep it off. The 330p gets discharged by the 330R and the voltage across the *R resistor turns on the BC547 to turn off the BC338. The 1N4148 absorbs the high-voltage flyback pulse. The circuit is only active for a very short period of time and off for a longer period of time. This delivers a small amount of energy to the high powered LED and allows the LED to be connected to a 12v supply (via the circuitry).

THE FLYBACK OSCILLATOR

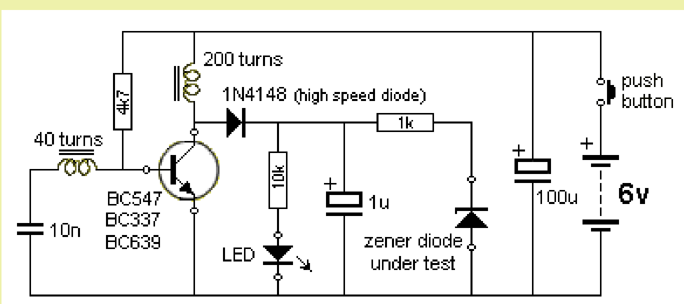


Fig 97a

A flyback oscillator is any oscillator where the transistor turns off quickly and abruptly during part of the cycle and allows the energy (the flux) in an inductor to collapse suddenly to produce a high voltage IN THE OPPOSITE DIRECTION. The circuit in **Fig 97a** consists of a transformer with a feedback winding of 40 turns. It can be constructed as a piece of test equipment to test transistors, zeners and LEDs.

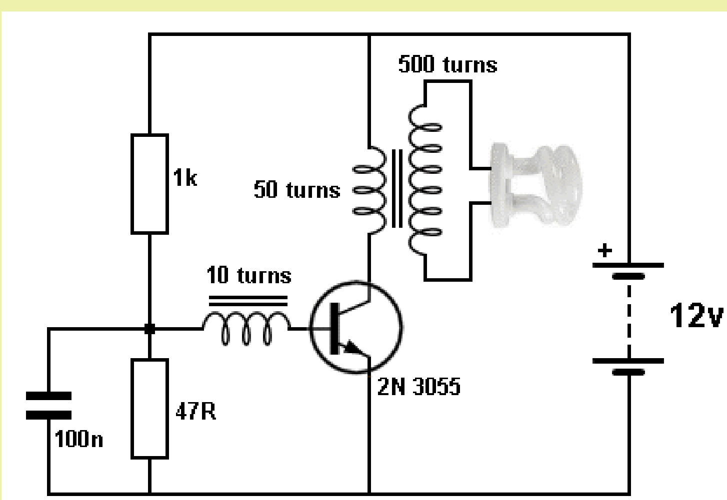


Fig 97a-aa

FLYBACK OSCILLATOR

This circuit is a very good example of a flyback transformer in operation.
The CFL needs a very high voltage to strike (start the illumination) when the anodes (all projections into a glass tube are called anodes) are not heated.
You cannot use the "turns-ratio" (50:500 in this case) to determine the output voltage because the transformer is used in its "collapsing mode."

This circuit will drive a 5watt CFL tube from an old CFL lamp

Fig 97a-ab

from 6v or 12v. It makes a very handy emergency light.
The transformer is made by winding 500 turns for the secondary.
This consists of winding about 10 turns on top of each other before advancing along the rod. The rod can be round or flat, from an old AM radio. It is called a ferrite rod. The 500 turns have to be added before reaching the end and this means 100 turns has to take up 1/5th of the distance. This reduces the voltage between the turns as the enamel will only withstand 100 volts.
Before you start winding, use at least 3 layers of “sticky-tape” to prevent the high voltage shorting to the rod.
The size of the wire is not important and anything 0.25mm or thinner will be suitable. After winding the secondary, the primary is 50 turns and the feedback is 10 turns.
The primary can be 0.5mm wire and the feedback 0.25mm.
Connect the transistor, components and tube and turn the circuit ON very briefly. If the tube does not illuminate immediately, reverse the wires to the feedback winding.
The transistor must be 2N 3055 (or the plastic version, TIP 3055). It will get warm when illuminating the lamp and needs to be heatsinked. The lamp must not be removed as the circuit will overload and damage the transistor.
The circuit takes 250mA when driving a 5 watt CFL (or 18 watt fluorescent tube) on 12v supply. The 1k base resistor can be reduced to 820R and the brightness will increase slightly but the current will increase to 500mA.
The circuit is more-efficient on 6v. The 1k base resistor is reduced to 220R and the transistor remains cool.

THE BOOST CIRCUIT or BOOST CONVERTER

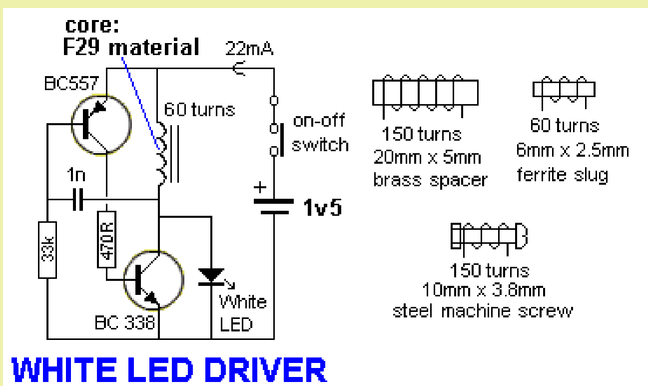


Fig 97aa

Any circuit that converts a low voltage to a higher voltage is classified as a **BOOST CONVERTER** or **BOOST CIRCUIT**.
Fig 97aa will drive a super-bright white LED from a 1.5v cell.
The 60 turn inductor is wound on a small ferrite slug 2.6mm dia and 6mm long with 0.25mm wire.
The main difference between this circuit and the two circuits above is the use of a single winding and the feedback to produce oscillation comes from a 1n capacitor driving a high gain amplifier made up of two transistors.
The feedback is actually positive feedback via the 1n and this turns on the two transistors more and more until finally they are fully turned on and no more feedback signal is passed though the 1n. At this point they start to turn off and the signal through the 1n turns them off more and more until they are fully turned off. The 33k turns on the BC557 to start the cycle again.

THE BUCK CONVERTER

Any circuit that converts a high voltage to a lower voltage is classified as a **BUCK CONVERTER**.
Fig 97b will drive a 1watt white LED from a 12v supply and is capable of delivering 300mA. The driver transistor is BD 327 and the inductor is 70 turns of 0.25mm wire wound on the core of a 10mH inductor. The voltage across the LED is approx 3.3v - 3.5v The 1R is used to measure the mV across it. 300mV equals

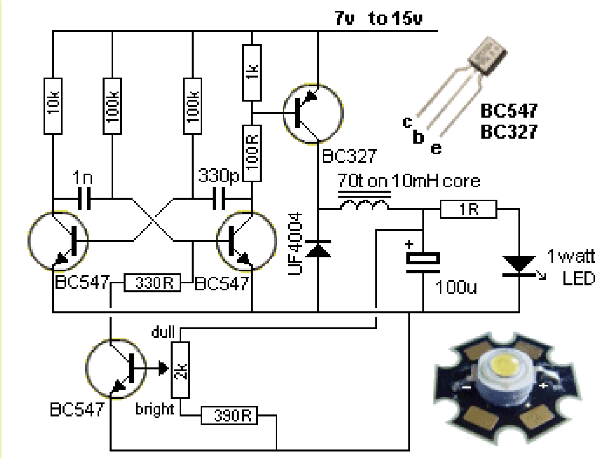


Fig 97b

300mA LED current.
The diode MUST be high speed. A non-high-speed diode increases current 50mA.
This circuit is a very good design as it does not put peaks of current though the LED.

MORE OSCILLATORS

The Armstrong, Clapp, Colpitts, Hartley, Wien Bridge and even unknown oscillators like the one below all use capacitors, resistors and coils to create a circuit called a RESONANT CIRCUIT and these two components produce a sinewave when they receive a pulse of energy.

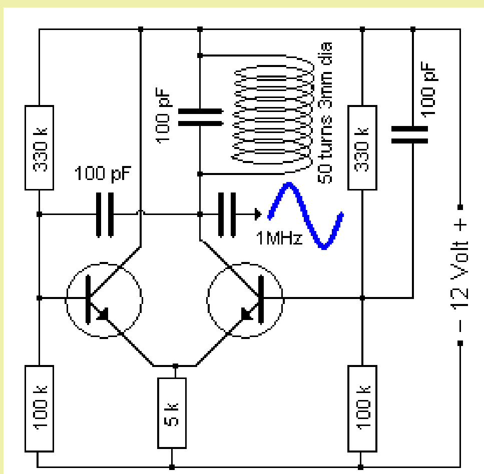


Fig 98.

We are going to lump all these oscillators together as they are variations on a similar design. There are two common oscillators that can be recognised by the layout of the circuit. The Colpitts oscillator has 2 capacitors across the coil with the signal taken from the join or it may have a tuned circuit with the signal taken from the active end. The Hartley Oscillator has a tapped coil and these are difficult to obtain.

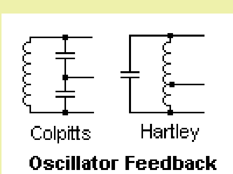


Fig 99.

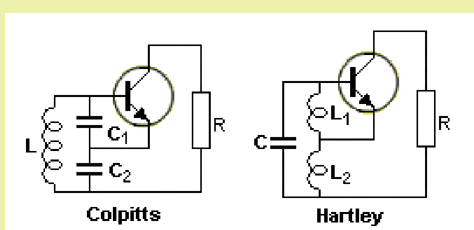
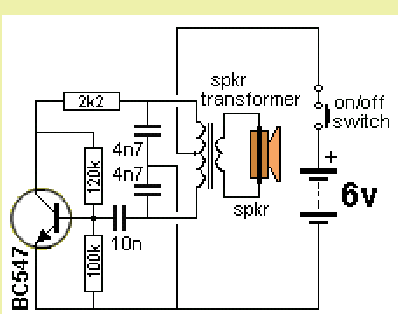


Fig 99a



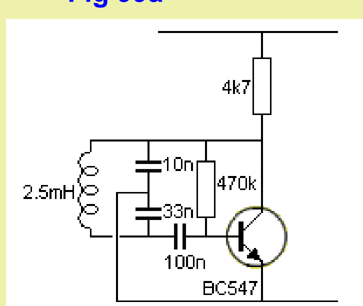


Fig 101. Colpitts Oscillator

Fig 100. Colpitts Oscillator

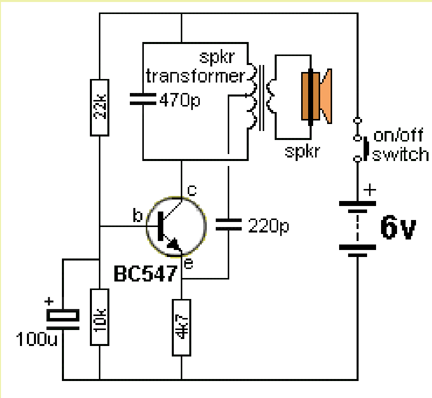


Fig 102. Hartley Oscillator

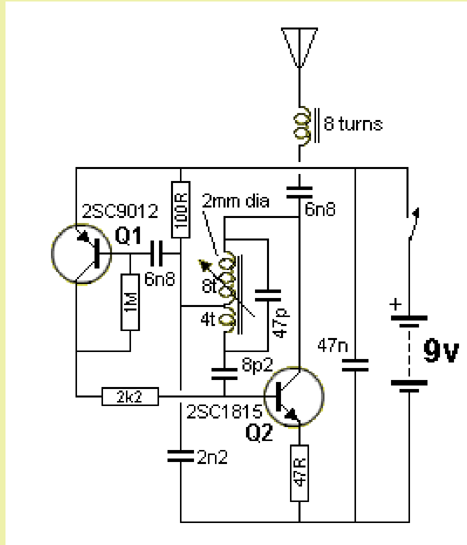


Fig 103. Hartley Oscillator

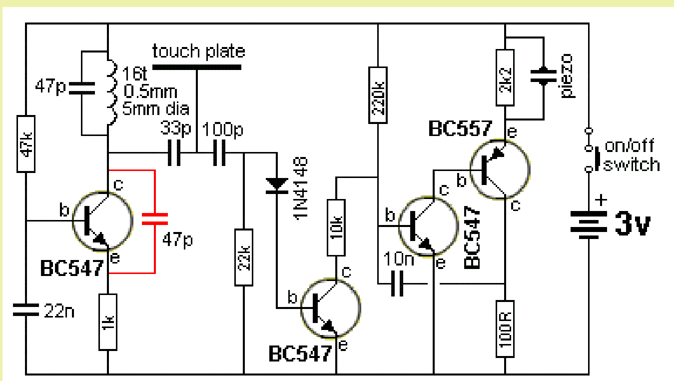


Fig 103a. Door Knob Alarm

DOOR-KNOB ALARM

This circuit can be used to detect when someone touches the handle of a door. A loop of bare wire is connected to the point "touch plate" and the project is hung on the door-knob. Anyone touching the metal door-knob will kill the pulses going to the second transistor and it will turn off. This will activate the "high-gain" amplifier/oscillator.

The circuit will also work as a "Touch Plate" as it does not rely on mains hum, as many other circuits do.

The first transistor is a **Colpitts Oscillator** and the feedback is via the 47p. Explaining the operation of this oscillator could take a page of discussion. We are only going to explain one amazing feature - how the oscillator creates the second half of its cycle. We know how the stage turns on (via the base-bias resistor) - but how does it turn OFF to create the other half of the waveform. Here's how:

We know that when a transistor turns ON, the collector voltage falls and the emitter voltage rises. Simply joining these two points with a resistor or capacitor will not produce feedback as one is falling and the other is rising. We need to join two points that are rising AT THE SAME TIME.

The secret comes from the inductor. The 16 turns of wire produces a voltage in the opposite direction when the transistor is turned off.

In the first diagram of fig 103b we see the transistor turned ON and current flows through the coil. The voltage at the bottom of the coil will be slightly lower than the supply voltage. When the transistor is turned off, it is effectively out of the circuit and the current flowing through the coil produces magnetic flux that will collapse very quickly and produce a voltage across the ends of the coil that will be OPPOSITE to the applied voltage. This means the voltage at the bottom of the coil will be HIGHER than rail voltage and we can think of the coil rising above the power rail and producing a voltage 2, 5, 10 or even 100 times higher than the power-rail voltage.

This is the amazing fact about a coil (inductor) and is the secret behind the operation of this circuit.

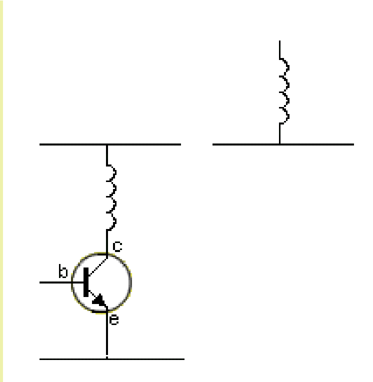


Fig 103b.

In circuit 103b, this high voltage is produced at some point in the cycle and it pulls the emitter UP a small amount via the 47p and this turns the transistor OFF. We are not going into what part of the cycle produces the high voltage via the inductor but it DOES. That's how the circuit produces the second part of its cycle. The inductor produces a high voltage that starts to turn off the transistor and this allows the inductor to produce a higher voltage and the transistor is turned off even more. During this time the 47p feedback capacitor is charging and RISING.
Most oscillators are described on the web and you can decide which type you need for your particular application.

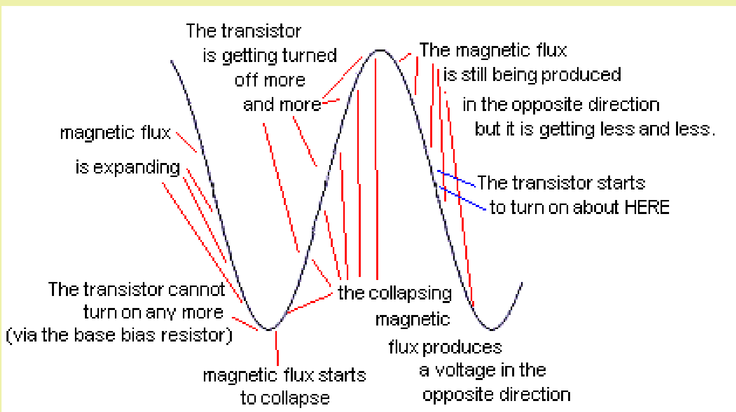


Fig 103c.

THE FEEDBACK CAPACITOR

The author was asked how to work out the value of the feedback capacitor in an oscillator.
There are many different oscillator circuits and in some oscillators, the feedback capacitor sets the frequency of operation for the circuit.
Rather than trying to work out the value mathematically, it is best to refer to a circuit that is already operational and copy the value. You will be able to increase or decrease the value 30% to get your required frequency but any value less than 50% may not produce enough feedback to keep the circuit oscillating.
You may need to increase the base-bias on the transistor to give the transistor more gain.
In some oscillator circuits, the feedback capacitor does not set the frequency. It is determined by a capacitor and coil in a TANK CIRCUIT.
The same suggestion applies. Refer to a circuit that already operates at the frequency you require and use the same value capacitor.
You can halve the value and double the value and use a number of different transistors to make sure the circuit still operates.
This proves the value you have selected is not at the extreme limit of operation.

OSCILLATOR SUMMARY

Look for a TUNED CIRCUIT and feedback line. It will be an oscillator.
Most have a high-impedance output and must be connected to a circuit that will not "load" them (and reduce the amplitude of the output) or prevent them oscillating. But some oscillators have a very low output impedance and can drive a low-impedance device. You have to be aware of these features.

HOW AN OSCILLATOR STARTS

All oscillators start-up due to noise. In most cases this noise comes from a spike or peak of current that occurs when the circuit is turned ON.
That's why some oscillators will not start if the voltage gradually rises. Uncharged capacitors present a very small resistance and allow a high current to flow (relatively speaking) to other components and this starts the circuit operating.
In addition we have the situation where a transistor produces a small amount of noise in the base-

emitter junction when a current flows through the junction. This noise gets amplified by the transistor and appears on the collector.
Other circuits rely on the transfer of the spike from the collector to the base due to the capacitor being uncharged.
Some circuit rely on the fact that a tuned circuit starts to produce a waveform when it receives a spike of energy and this waveform is amplified by the transistor.
Other circuits rely on the waveform produced by a crystal when it receives a spike of energy.
Some oscillators are very reliable as self-starting, while others need the right voltage and very little loading on the output to be reliable.
You can test an oscillator by gradually increasing the voltage and see if it self-starts.
The starting waveforms can be so minute that you cannot detect them.

IMPEDANCE MATCHING

Every electronic component has a value of resistance. You can measure this value with a multimeter. But sometimes the value changes according to the light it receives, the frequency it is operating-at, or the voltage it is connected-to, or the sound it receives, or its temperature or many other influences.
Sometimes the output from a circuit might be 2v, but if you put a low-impedance device such as a speaker on the output, it "kills" the sound.
Or you may have a nearly flat 9v battery. It measures 5v with a multimeter but when you connect a 3v motor, it does not work.
These are both examples of poor IMPEDANCE MATCHING - yes, the battery has a HIGH Impedance and that's why it cannot deliver the current required by the motor.

What is **IMPEDANCE MATCHING**?

Impedance Matching is is connecting two items together so: "THEY WORK."

Some devices PRODUCE or DELIVER a signal or a voltage or a current.
Some devices ACCEPT a signal or voltage or current.
We need to connect these types of devices together.

Let's start with those that DELIVER:
An amplifier may be able to produce an output of 2v, but when a low-impedance device (low resistance device) such as a speaker is connected, it cannot deliver the CURRENT needed to drive the speaker.
The same with a flat 9v battery. It cannot deliver the CURRENT needed to drive a 3v motor.
You cannot "test" or measure the output capability of a device. You must connect it to the input of the project you are designing and measure the waveform or voltage being delivered (or transferred).
If the voltage or waveform is considerably less than when it is not connected, you have decide if the attenuation (reduction) is acceptable. The ideal situation is NO attenuation - but in nearly all cases you will get some attenuation.

There are no "rules to follow" and every case is different. However when the output of a device is NOT reduced when it is connected to a circuit, the two items are said to be IMPEDANCE MATCHED.

There are three ways to "Match Impedances:"
1. via a resistor. This is generally a poor way to match impedances and is very inefficient. But it may be the only way to connect two devices.
2. via a capacitor. This can be a very good way to match impedances.
3. via a transformer. Generally the most efficient way to match impedances but requires a lot of calculation and expense in getting the transformer designed and manufactured.

Impedance Matching can also be referred to as "MATCHING" and the simplest example is connecting a 6v globe to a 12v battery. This is called "Resistance Matching" or "Current Matching" or "Voltage Matching" because the resistance, voltage and current are known quantities.
[To connect a 6v globe to a 12v battery you can use a resistor or put two 6v globes in series. Using a resistor will be very difficult because a globe requires about 6 times normal current to allow it to start illuminating and then it takes the "rated current."]
But when when a device produces a signal; the voltage, resistance and current changes during the production of the signal and because these values are not constant, we use the term **IMPEDANCE MATCHING**.
Impedance really means "resistance that changes during the production of the waveform."

Impedance matching can be worked out mathematically, but you need to know all the parameters of the device and the circuit you are connecting together. This is rarely possible to obtain.
Rather than calculate the result, it is much easier and more-accurate to connect the two items and view the result on a CRO (Cathode ray Oscilloscope). But if you cannot do this, simply connect them and listen or view the output from a speaker, relay or LED etc.

We have already studied "Impedance Matching" in the circuits above, but did not identify the concept. We will now go over some of the circuits and show where impedance matching took place:

In **Fig 6**, the transistor matches the HIGH IMPEDANCE of your finger to the LOW IMPEDANCE needed to turn on the LED.
The transistor converts the 50k resistance of your finger to less

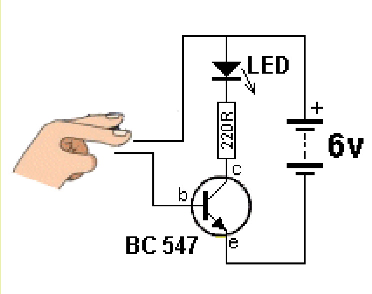


Fig 6

than 0.5k (due to the gain or amplification of the transistor of about 100 -200).
You can also say it matches the HIGH RESISTANCE of your finger to the LOW RESISTANCE needed to turn on the LED.

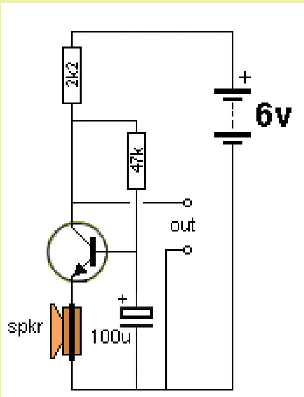


Fig 64

In **Fig 64**, the transistor matches the LOW IMPEDANCE of the speaker to produce a HIGH IMPEDANCE output on the "out" terminals, suitable for delivering to the input of an amplifier.
The transistor converts the 8 ohms of the speaker to more than 800 ohms (possibly 1600 ohms) due to the gain or amplification of the transistor (about 100-200) and at the same time the 0.5mV produced by the speaker is amplified to about 40mV to 80mV.

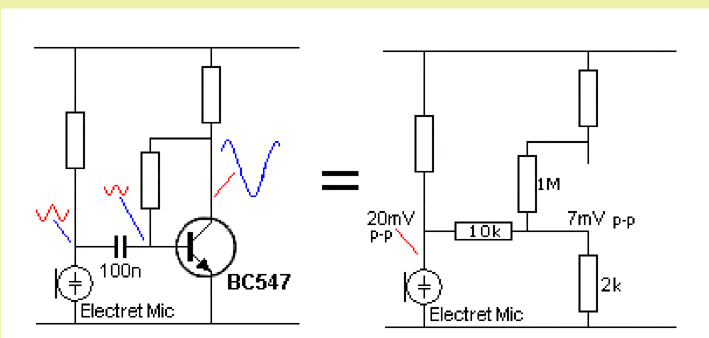


Fig 71f

The 100n capacitor in **Fig 71f** matches the impedance of the electret microphone to the input impedance of the transistor.
The impedance of the electret mic is about the same as the input impedance of the transistor but the mic needs about 0.5mA to operate and the voltage on the base of the transistor needs to be very accurately set for "self bias."
A capacitor separates these slightly different DC values while passing the AC signal..

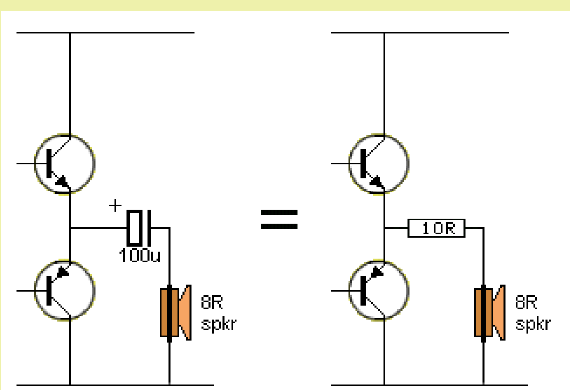


Fig 71e

Sometimes Impedance Matching is needed to separate or remove the DC component of a signal. In **Fig 71e**, the electrolytic matches the LOW IMPEDANCE output of the amplifier to the LOW IMPEDANCE of the speaker. The two impedances are almost identical and you could connect the speaker directly to the output of the amplifier, but the output has a voltage of approx mid-rail and this would enter the speaker and shift the cone when no audio is being reproduced. And the speaker would only be able to amplify the negative part of the waveform.
To remove the DC component of the waveform, an electrolytic is included.

SATURATING A TRANSISTOR

This is the last topic for discussion because it is the last thing to attend to when designing a circuit.
We have explained the fact that a transistor turns ON when the base voltage is above 0.7v and the current though the collector-emitter leads is approximately 100 times the base current.
This means a transistor with a gain of 100 will deliver 100mA to a collector LOAD when 1mA enters the base.
This is theoretically true and will occur in nearly all cases, but some devices such as motors and globes need a lot more current to get them started or to get them to turn **ON** because the cold resistance of a globe is only about 1/5 its hot resistance. This means a 100mA globe needs 500mA to get it to start to glow.

The same with a motor. The starting or "stalled current" is 5 times more than the operating or "running current.
On top of this the transistor might not have a gain of 100 and the voltage may be slightly higher than expected. All these things means the transistor must be turned **ON** with more than 1mA into the base.
If you deliver 2mA, it does not mean the transistor will deliver 200mA to a LOAD. If the load requires 100mA, delivering 2mA to the base will simply turn the transistor **ON** harder and the collector-emitter voltage will be slightly lower, but the load will still draw (or take) 100mA.
But the devices we mentioned above require 500mA to get them started, so the base current needs to be 5mA.
Now, here's the unfortunate part, 5mA base-current will not deliver 500mA collector current. The transistor needs more than 5mA base-current to get it to deliver this HIGHER current. It needs about 7mA.

This process can be proven by experimentation.
Simply increase the base current until the device is turned **ON**, then measure the base current. Add 1mA to 3mA to guarantee reliability and the circuit is complete.
This process is called **SATURATING A TRANSISTOR** or **GUARANTEEING TURN-ON**, or **FULLY SATURATING the TRANSISTOR** or **FULLY TURNING the TRANSISTOR ON**.

HYSTERESIS (see also Schmitt Trigger above)

Hysteresis is a feature of a circuit. It is when the circuit turns on at a particular voltage and turns off when a higher or lower voltage is reached. The gap between these two voltage-levels is called the **HYSTERESIS GAP.**
This is a very handy feature.
It prevents an effect called "hunting."
If a circuit turns on at say 6v, and turns off at 5.7v, any slight variation in the supply voltage will cause the output to change state. This may produce an undesirable effect of the circuit turning "on and off" at the wrong time due to supply voltage fluctuations. By increasing the gap between these two voltages, the circuit will remain in one state or the other - until the input voltage (the controlling voltage) increases or decreases.
The **Schmitt Trigger** (Fig 79a) is an example of a circuit using **Hysteresis**.
Any circuit with a positive feedback line, introduces the effect we are talking about.
The feedback line has the effect of assisting the input voltage.
In other words, it widens the gap between an ON state and an OFF state.
This is called POSITIVE FEEDBACK because it ADDS to the effect of the input voltage.
Even when the input voltage is falling, the feedback improves the ON or OFF state by taking the circuit past the point where the change takes place.
Rather than thinking of the feedback as "positive," consider it as AIDING.
All **HYSTERESIS** feedback is **AIDING** or **ASSISTING** the effect you are trying to produce.

This circuit uses Hysteresis. The main "assisting component" is the 22k.

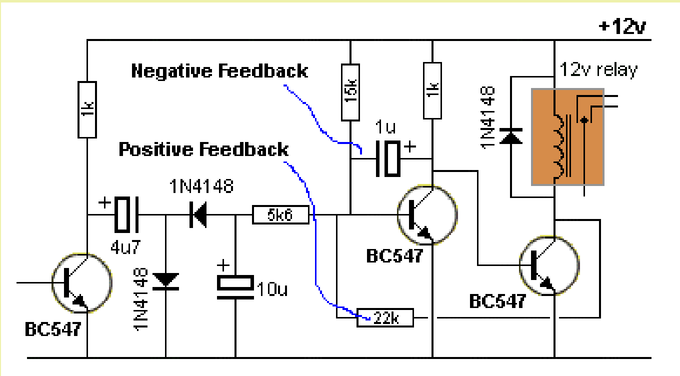
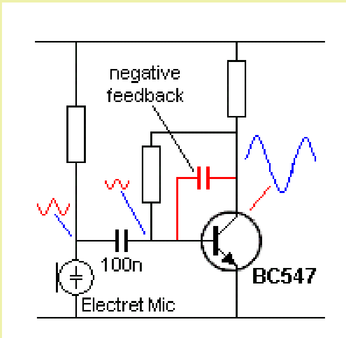


Fig 103cc

This is how the circuit works:
When the circuit is turned on, the base of the second transistor gradually develops 0.6v and the transistor turns ON.
The voltage between collector and emitter is about 0.2v and the third transistor is OFF.
When the first transistor receives an AC signal, an increasing voltage on the base causes the collector voltage to reduce and the charged 4u7 electrolytic moves towards the 0v rail. The negative lead of the 4u7 goes below the 0v rail by about 0.6v.
This allows the second diode to discharge the 10u electrolytic and the 0.6v on the base of the second transistor is reduced. Let's say it is reduced to 0.55v.
This causes the second transistor to turn off and the positive lead of the 1u electrolytic rises toward the 12v rail. The negative lead of the 1u rises too and this makes the transistor turn ON. In this process the 1u starts to charge and it has the effect of slowing down the "turning ON" of the second transistor.
But the pulses keep coming from the first transistor and 10u is kept discharged. The 1u keeps charging and eventually it is fully charged and now the pulses from the first transistor can finally turn off the second transistor.
The third transistor is turned ON and the 22k connected to the collector of the third transistor reduces

the voltage on the base of the second transistor by about 0.15v
This helps the pulses from the first transistor to keep or put a low voltage on the base of the second transistor and even if these pulses stop, the voltage on the base will take time to rise via the 15k and this is called the **HYSTERESIS GAP.**
When the circuit changes state, the pulses from the first transistor will discharge the 10u and this will be "fighting against" the 15k and 22k resistors that will be trying to charge the 10u.

NEGATIVE FEEDBACK



The circuit shows a capacitor between the base and collector. It provides **NEGATIVE FEEDBACK.**
If we remove the capacitor, when the base "moves down," the collector "moves up." In other words the signal is inverted.

When the capacitor is fitted, we have to start with the collector because it has more "power" and it is the lead that is driving the action of the capacitor and then go to the base.
When the collector voltage "moves down" the right plate of the capacitor moves down and it charges and tries to pull the left plate down too.

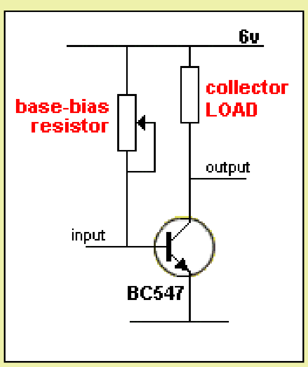
This is the opposite effect to the signal moving through the transistor.

This means the capacitor is working against the action of the transistor.

The capacitor will have more effect on high frequency signals while the low-frequency signals will be affected less.
Because the capacitor is working against the natural flow of signal through the circuit, it is called NEGATIVE ACTION or **NEGATIVE FEEDBACK**.

BIASING THE BASE

The base of a transistor can be biased in many way. In other words, the current to be supplied to the base can come from many different parts of the circuit and delivering it is much more complex (complicated) than you think.
Before we go into the section on SELF-BIAS, we will look at the problem of adding a base bias resistor between the base and supply-rail.
In the following diagram a resistor is placed between the base and 6v supply.
If we select the correct value for this resistor, the circuit will produce the HIGHEST GAIN !!!!
This is the best gain you can get. But the circuit has a lot of drawbacks and difficulties.



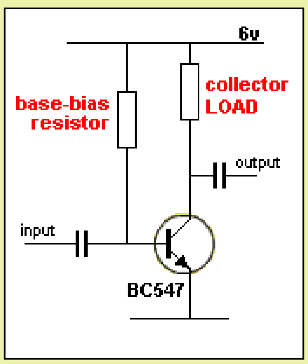
THIS CIRCUIT HAS THE HIGHEST GAIN !!!
It is NOT a "self-biased" stage

If you select a resistor for the LOAD and then select the base-bias resistor so that the transistor turns ON and produces a voltage on the base that is half-rail voltage, this circuit will produce the best and highest amplification of ALL designs. If the transistor has a gain of 250, the circuit will produce a gain of 250. If the transistor has a gain of 450, the circuit will produce a gain of 450.
BUT it will be very difficult to select the correct value. So we will use a variable resistor.
If the surrounding temperate of the project increases, the base-emitter current will increase and the collector voltage will decrease. The same will happen if the rail voltage increases. And the transistor will multiply the effect 250 to 450 times.
This circuit is suitable for an individual design where the base-bias resistor can be selected to suit the transistor but for mass-production and reliability over a wide range of transistors, the circuit needs individual attention to get the biasing correct.
But it is not suitable for mass-production as the gain of the transistor is very critical.
The pot on the base is only used to set-up the circuit and is replaced with the correct-value resistor.
In the SELF-BIASING stages discussed below, the voltage on the collector is fairly stable and fixed due to the base-bias resistor being connected between base and collector.

This feature is not provided on the circuit above and if you want the collector voltage to sit at 0v (actually about 0.15v) when the stage is turned ON, this is the circuit you must use.
Once you have selected this type of circuit, you need to select the LOAD resistor. This is will be as high as possible so the circuit takes the least current.
That's because the LOAD resistor will be effectively across the rails for most of the time.
Now select the base-bias resistor so the transistor decreases the collector voltage to zero.
Start with a very high base-bias resistor and monitor with collector voltage with a digital multimeter so you don't put any load on the circuit.
Decrease the value of the base resistor until the collector voltage reaches 0v.
This circuit will operate differently to a self-biased stage.
It will only respond to a waveform or signal that LOWERS the voltage on the base. This signal will TURN OFF the transistor and the collector voltage will RISE.
The input and/or the output can be capacitor-coupled to other stages and this arrangement will produce the maximum collector-voltage swing.
Here is the main problem with the circuit.
If you adjust the stage so the collector voltage is at 0v (0.15v) you have selected the correct value for the base resistor. But if you decrease the value by 50%, the collector voltage will not fall to a lower voltage but the transistor will be turned on HARDER.
This means the transistor is turned on HARDER than necessary and the input signal will have to be larger (higher amplitude) to turn the stage OFF.
In other words, you will have decreased the gain of the stage by using a low-value base resistor.
We say "decreased the gain of the stage" because it will require a higher input signal. The actual gain of the transistor will be 250 or 450 but the "effectiveness" will be reduced.
If the base-bias resistor is TOO LOW, the stage will have an "effectiveness" less than 250, and maybe less than 50. That's why seeing the value of the base-bias resistor is so critical. The transistor must be biased to the point where the voltage on the collector is just at the point of reducing to less than 0.5v

COMPARISON

To give a comparison, this circuit will produce a gain of about 250 with a transistor having a gain of 250, but if the base-bias resistor is placed between the base and collector (as shown below - to produce a self-biased stage) the stage will have a gain of about 70 -100.



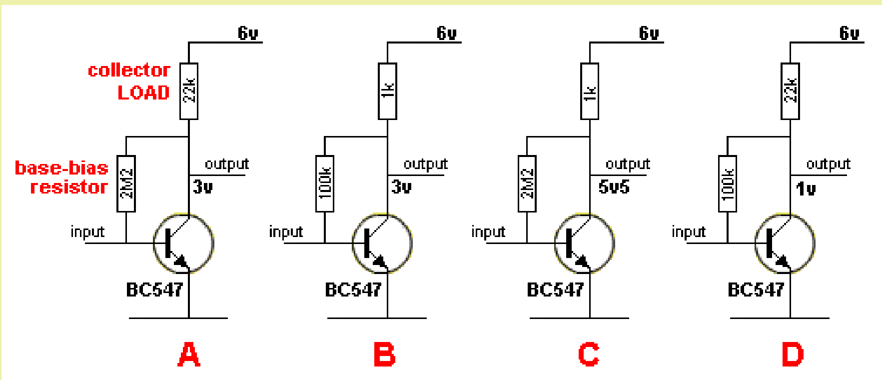
We will now cover some of the ways to bias a transistor using the SELF-BIAS arrangement.
We will consider a transistor has a gain of about 100 in a "self-biased" stage. (It can be as low as 10 or as high as 200).
This means the collector-emitter circuit can only deliver 100 times more current than is being supplied to the base.
But current supplied to the base is "wasted current" as it flows ALL THE TIME and for battery operated circuits, this current must be kept as low as possible.
Secondly, a transistor can only deliver current up to the maximum rated value for the transistor. If the maximum current is 100mA, a current of 1mA into the base will allow the transistor to deliver 100mA via the collector-emitter circuit. That is: the load can take 100mA. But as the current reaches the maximum value, the transistors gain decreases. This means a base current of 1mA will only allow the transistor to deliver about 50mA. As the output current requirement increases above about 50%, the base current must be increased.
This is one of the hidden problems with a transistor. It may take 2mA base-current to get to 70mA, 5mA to get to 80mA and 10mA to get to 100mA.
This is a big difference as the gain can drop from 100 to 10.
This is one of the factors you have to be aware of.
That's why the gain of a transistor is generally given for 10mA collector-current.

Working out the value for the base current is a big problem and we are going to cover only the small-signal stage.

BASE CURRENT

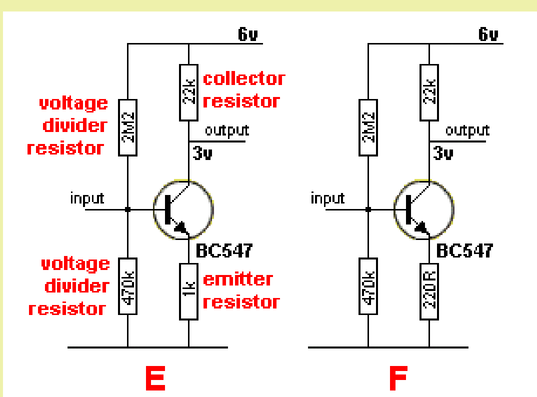
The following 4 diagrams show how base current is delivered to a small-signal stage in a "self-biasing" arrangement.
In this arrangement, the **base-bias resistor** is selected so the voltage on the collector is half-rail

voltage. In this case it is 3v.
Circuits **A** and **B** have 3v on the collector.
But circuit **A** takes less current when "sitting around." Circuit **B** takes 22 times more current. This is due to the collector load.
Why select circuit **A** or **B**?
We have already learnt the current delivered to the next stage in a circuit depends on the current flowing through the COLLECTOR LOAD resistor. Refer to **Fig 13** and **Fig 62.**
This means circuit **B** will deliver more current.
One other factor you have to remember, is this: Circuit **A** requires a very small input current. Circuit B requires about 20 times more current. You can think of it this way: The input energy (that is the input voltage-and-current) is "fighting against" the base-bias resistor. It is much-easier to fight-against a 2M2 resistor as it is delivering much less current (to the base) than a 100k resistor.
Let's explain what we mean by "fight against."
For circuit **A**, the 2M2 is delivering current to the base. When the input current increases, the transistor is turned on MORE and the collector voltage falls. This means the current via the 2M2 reduces. This means you have to supply more base current to turn the transistor on.
Circuit **B** has a 100k base-bias resistor but the main criteria in turning the transistor ON is the large amount of current required by the base to get current-flow in the collector-emitter circuit so that a voltage-drop is developed across the 1k resistor. 22 times more current is required to get the same voltage-drop produced in circuit **A**.
Circuits **C** and **D** show the wrong combination of resistors, making the collector voltage too high or too low. If it is too high or too low, the stage will not (equally) amplify the positive and negative excursions of the input signal. However, this may be what you want.



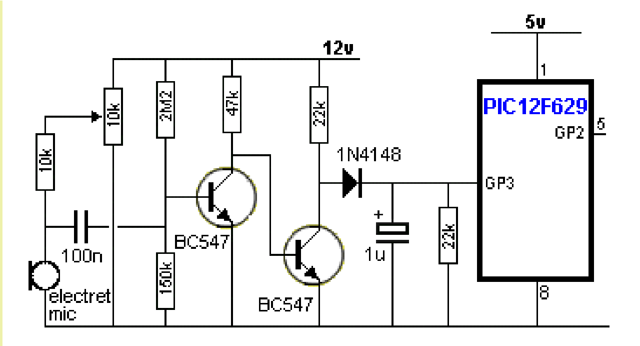
"Self Biased" stage

The second type of biasing is called a "Bridge" or "H-Bridge." Circuits **E** and, **F** show two bridge circuits.
Circuit **E** is very similar to circuit **A**. It needs about the same input current to circuit **A** and has about the same output-current capability.
However circuit **E** has a gain of about 22. Circuit **A** has a gain of about 70 to 100.
The gain of circuit **E** is defined as collector resistor divided by emitter resistor 22k/1k = 22.
The gain of circuit **F** is about 100.
Circuits **A** and **F** produce about the same gain and the only difference is two extra resistors in circuit **F**.
The only problem with circuits **E** and **F** is the rail voltage must be above 4v. If the rail voltage is less than 3v, the transistor will not be turned ON as the base will see less than 0.6v. **The "self biased" stage will operate down to about 1v rail-voltage.**



"Bridge" stage

The third type of circuit is biased just below the voltage needed to turn the transistor ON.
This stage takes very little quiescent current but the supply voltage cannot rise a large amount as this will turn the transistor ON and change the characteristics of the stage.

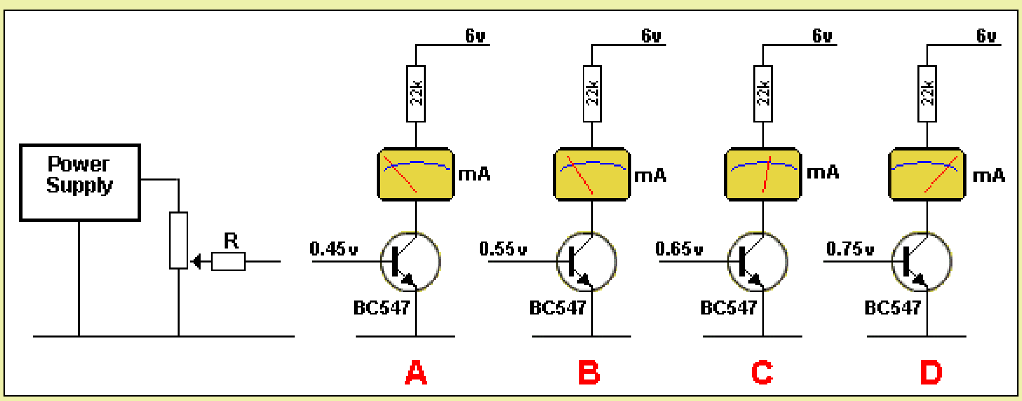


The first transistor is biased "OFF"

The starting point is to bias the first transistor so the voltage on the base is just at the point of turning it ON.
This allows the 47k resistor to turn on the second transistor and the diode does not see any voltage.
This means the 1u does not get charged and the input to the microcontroller sees a LOW.
This is called the QUIESCENT (standing, stand-by or idle) condition.
The gain of the electret microphone is adjusted by the 10k pot and when it receives a loud audio signal it produces an output of about 20mV.
This signal is sufficient to turn ON the first transistor and turn OFF the second transistor so that signal diode sees a HIGH pulse via the 4k7.
This voltage is passed to the 1u and it gradually gets charged. When the voltage on the 1u reaches about 4-5v, the microcontroller sees a HIGH and the program in the micro produces an output.
The main problem with this circuit is the 20mV required to turn on the first transistor.
Different transistors have varying base voltages. You will need to set the base voltage very accurately for the circuit to work.

What do we mean by: **DIFFERENT BASE VOLTAGES**?
Most silicon transistors start to turn ON when the base voltage reaches 0.65v. But some transistors start at 0.55v. And some transistors are fully turned on at 0.7v while others need 0.75v.
These different voltages are not important in most cases except for the circuit above that keeps the transistor turned off until required.

We are now going to show how a transistor TURNS ON. In this discussion, the base voltage is delivered from an adjustable power supply
An NPN transistor is not turned on AT ALL when the base voltage is below 0.45v. This is shown in diagram **A**:

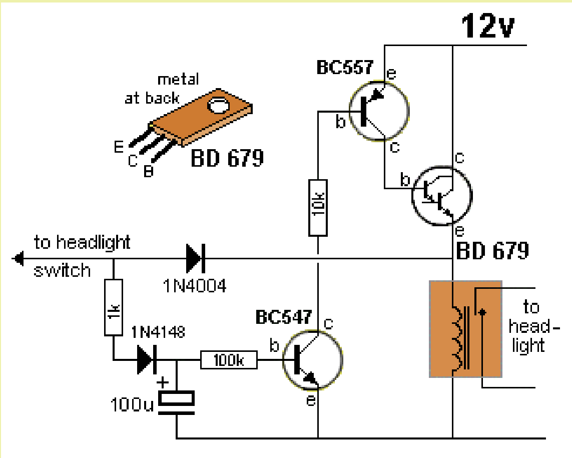


As soon as the base voltage reaches 0.55v, the transistor starts to turn ON. This is shown in diagram **B**.
A transistor is a current-controlled device and this is how it works:
As the voltage from the power supply is increased from 0.50v to 0.55v, current will start to flow into the base and the transistor will start to turn ON. The transistor will turn on MORE when the base voltage rises to about 0.65v.
The value of 0.65v shown in diagram **C** just lets you know the transistor is turned on a certain amount. It's a characteristic voltage produced by the transistor that we have no control over.
When we read this voltage we know the transistor is a point of just being turned ON. Another way to look at the situation is this: The transistor detects how much current you are delivering from the power supply and it delivers about 100 times this amount through the collector-emitter circuit.
Here's the highly technical part: The voltage from the power supply must be CURRENT-LIMITED. This is done by adding the resistor **R**. The voltage from the power supply flows through resistor R and allows the transistor to develop a base voltage called a CHARACTERISTIC VOLTAGE or BASE VOLTAGE. This is a voltage developed by the transistor when a certain amount of current is flowing and by measuring this voltage we know how much current it is receiving. Adding the resistor allows the transistor to take the amount of current it requires. If we connect the power supply directly to the base, we will force extra current into the base and over-ride the natural requirements of the transistor.

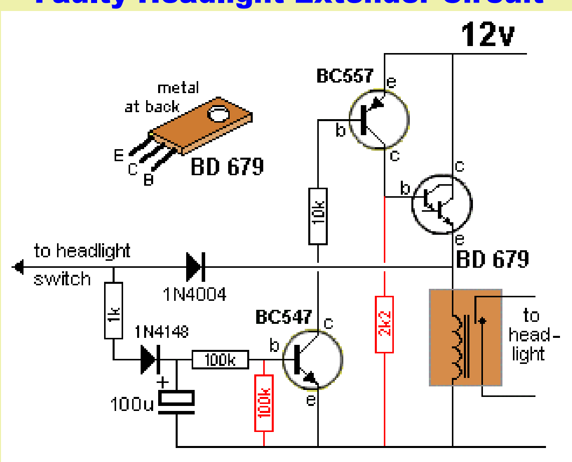
As you increase the voltage from the power supply, more current will enter the base and the voltage on the base will rise slightly to indicate the new value of current. This is shown as 0.75v in diagram **D**. The transistor will deliver more current through the collector-emitter circuit, but as the current increases to a maximum value (every transistor has a maximum allowable collector current), it may not be able to deliver 100 times more than the base current. It may be only 50 times or 10 times.
Increasing the current (further) into the base will have no effect on the base voltage. The base voltage is as high as it will go. The transistor is SATURATED (turned ON as hard as possible) and no further increase in collector-emitter current is possible. Increasing the current into the base will simply overheat the transistor and damage it.

LEAKAGE

This topic covers small, unwanted, currents produced when two or more transistors are connected together.



Faulty Headlight Extender Circuit



Headlight Extender Circuit - fixed

In the Faulty Headlight Extender Circuit we see 3 transistors directly connected together. When the 100u discharges, the BC547 turns OFF and this turns off the BC557 and also the BD679.
But the relay remains activated.
This is due to the BC547 not turning off fully and a very small current flows though the collector-emitter leads.
This current is amplified by the BC557 (about 200 times) and then by the BD679 (about 20,000 times). The resulting current is sufficient to keep the relay activated.
Two resistors are needed to turn the circuit off.
The 100k on the base of the first transistor discharges the 100u and makes sure the voltage on the base is zero so the transistor is fully turned off.
The 2k2 on the base of the BD679 does not remove the slight leakage current though the BC557 but it flows through the 2k2 and this produces a very small voltage-drop, that is too small to turn on the BD679, and this makes sure the BD679 turns off.

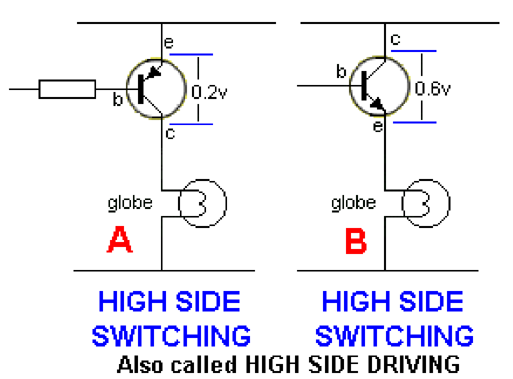
This type of problem will occur whenever two or more transistors are directly coupled together.
Even a leakage current of less than 1microamp will amplify to many milliamps with the gain of two or three transistors.

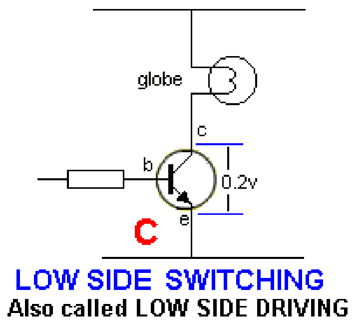
See more on leakage in [Spot the Mistake P27 Leakage.]

High-side Vs Low-side Switching

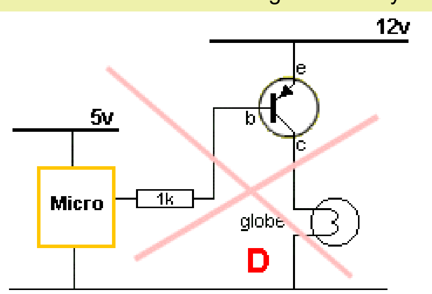
Devices such as globes, motors, relays etc are called LOADS. They can be placed above or below the driver transistor. When the driver transistor is above the load, as shown in diagrams A and B the circuit is called **HIGH-SIDE SWITCHING**. When the driver transistor is below the load, as shown in diagram C, the circuit is called **LOW-SIDE SWITCHING**.
The circuit for low-side switching is much easier to design and can be less expensive however high-side switching is the only arrangement available in cars and trucks as the load (globes and motors) are generally connected to chassis (to save wiring) and the control wire (power wire) comes from the positive of the battery.
For the **HIGH-SIDE SWITCHING**, the control line (the input to the base) can be active LOW (as in the first diagram). In the second diagram, the base is taken HIGH and the emitter follows. The voltage across the collector-emitter terminals will be higher

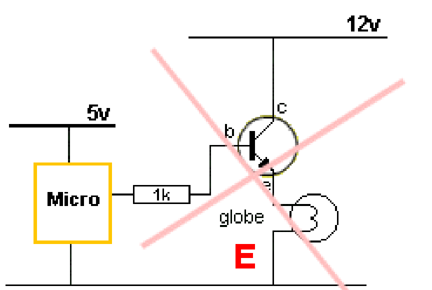
than the fist example and the transistor will get hotter. This is because the base of the NPN transistor cannot rise above the supply (in most cases such as cars and trucks) and the voltage between collector and emitter will be about 0.65v.





The three diagrams above show the voltage across the collector-emitter leads when the transistor is fully conducting.
In diagram **B** the transistor is an emitter-follower and the voltage is three times larger than diagrams **A** and **C**. This means the heat generated by the transistor will be three times larger than diagram **A** or **C**.





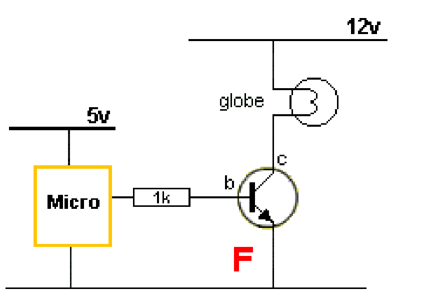
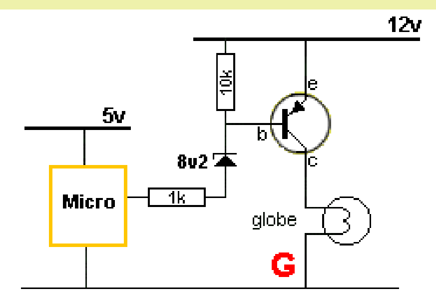


Diagram **D** shows the problem trying to switch a load on a 12v supply, from a 5v microcontroller. When the microcontroller is HIGH, the voltage is not high enough to turn off the transistor. The voltage on the base must be nearly 12v for the transistor to turn off.
This circuit will NOT WORK.
In diagram **E**, the voltage on the base will only rise to 5v,
and thus the globe will see only 4.4v and will not illuminate fully. The transistor will get fairly hot.
The solution is to drive the LOAD via LOW SIDE SWITCHING as shown in diagram **F**.

It is possible to switch a HIGH SIDE transistor from a microcontroller by including a zener diode so the transistor is turned off when the microcontroller is HIGH. The 10k resistor makes sure the base sees 12v when the micro is HIGH. The voltage of the zener is chosen so that when the micro is HIGH, the micro rail voltage, plus the voltage of the zener is more than the supply to the globe.



VOLTAGE TO CURRENT CONVERTER

This sounds very complex but it is very simple.
The simplest voltage-to-current component is a resistor.
A resistor performs lots of different jobs, depending on the circuit.

One of its jobs limits the current to a LED. It is called a CURRENT LIMITING RESISTOR. It can also be called a VOLTAGE TO CURREN2ONVERTER.
Here's how it works:

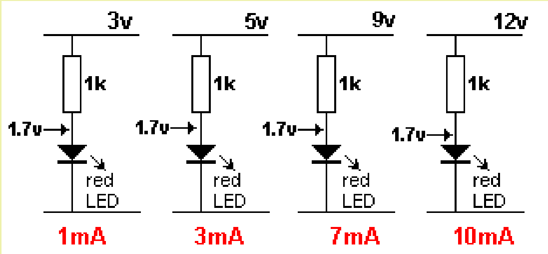


Fig 103d.
A resistor is a **VOLTAGE TO CURRENT CONVERTER**

A red LED must be delivered a voltage of exactly 1.7v for it to work. In other words it must be connected to a 1.7v supply.
But a 1.7v supply is very hard to obtain, so we use a 3v supply and a dropper resistor.
The resistor converts the 3v to 1.7v.
This is easy to understand because the 3v supply is fixed at 3v and when a voltage is delivered to the red LED it develops exactly 1.7v across it. The resistor sits between the 3v and 1.7v
When the voltage of the supply is increased, The voltage across the LED remains at 1.7v and the voltage across the resistor increases. This is shown in the diagrams above.
When the voltage across a resistor increases, the current through it increases. That's how we get 3mA, 7mA and 10mA. This is called VOLTAGE TO CURRENT CONVERSION.
The VOLTAGE on the input goes up and down and the CURRENT through the LED goes up and down. The input CURRENT will also go up and down but we are only covering the fact that the input VOLTAGE rises and falls and the output CURRENT RISES and falls.
Any circuit that produces this effect is called a VOLTAGE TO CURRENT CONVERTER.
A transistor can also be connected to produce VOLTAGE TO CURRENT CONVERSION.
The following circuit is an emitter-follower. It is also a VOLTAGE TO CURRENT CONVERTER. A rising and falling voltage on the input creates a rising and falling CURRENT on the output.
It also produces a rising and falling voltage on the output but we are only concerned with the fact that the circuit produces a rising and falling **CURRENT** on the output when the input **VOLTAGE** rises and falls.

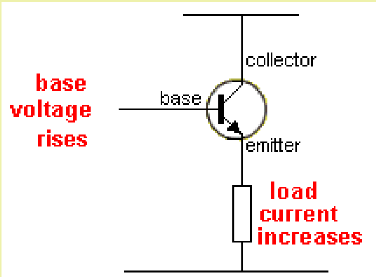


Fig 103e.
An emitter-follower is a **VOLTAGE TO CURRENT CONVERTER**

The circuit in **Fig103e** requires say 1mA input current. The output current will be 100mA. The circuit has the capability of increasing the current or AMPLIFYING the current. The resistor circuit above does not AMPLIFY the current. It is only a voltage-to-current converter.
The transistor performs a VOLTAGE TO CURRENT CONVERSION and also produces CURRENT AMPLIFICATION.
A common-emitter stage also performs VOLTAGE TO CURRENT CONVERSION.

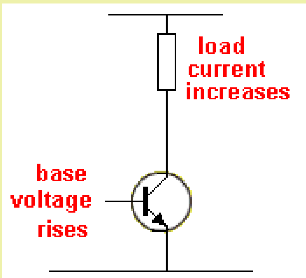


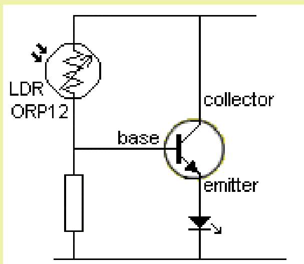
Fig 103f.
A common-emitter stage is a **VOLTAGE TO CURRENT CONVERTER**

A slight increase in the voltage on the base of a common emitter transistor will increase the current through the load by a large amount.

As you can see, there are lots of circuits that perform VOLTAGE TO CURRENT CONVERSION but we usually identify them for other features and that's why the term VOLTAGE TO CURRENT CONVERSION is rarely mentioned.
There are also special circuits (using op-amps) to perform precision voltage-to-current conversion, but we are concentrating on transistor stages.

ANOTHER VOLTAGE TO CURRENT CONVERTER

Here is another **VOLTAGE TO CURRENT** CONVERTER:
A photo detector (A light dependent resistor - LDR) produces a very wide change in resistance from dark to light conditions and when it is connected to a LOAD RESISTOR, the voltage across this resistor will change considerably.
But we cannot use this voltage-change to directly illuminate a LED or drive a motor because it does not have enough current. We need to convert this voltage-change to CURRENT-CHANGE.
The current through the resistor might be up to 1mA. A motor or LED or relay needs 10mA to 300mA.
Here is what we have:
We have a wide (large) change in **voltage** and require this to be converted to a wide change in **current**.
We say this voltage-change has very weak driving capability because it will not illuminate a LED or anything else.
We want a POWERFUL DRIVING CAPABILITY and that's what a CURRENT DRIVER is capable of doing.
In other words we want to convert a **WEAK** driver to a **POWERFUL** driver.



Current to voltage converter

When light falls on the LDR, the voltage across the resistor increases and this voltage-rise is detected by the base of the transistor and a small current passes into the transistor. The transistor amplifies this current and delivers up to 100 times more current to the circuit created by the collector-emitter terminals. The LED is in this circuit and the LED will illuminate brightly when 5 to 25mA flows. This is only a demonstration circuit to show the effect of shining a light on the LDR. It may cause the LED to shine too bright and be damaged as no current-limiting resistor has been included to protect the LED.

CURRENT TO VOLTAGE CONVERTER

A resistor can be used as a **CURRENT TO VOLTAGE CONVERTER**.
Fig 103g shows a resistor called a **SENSE RESISTOR**.
It is a low-value resistor in series with one line of a circuit and its function is **not to change** the operation of the circuit in any way.

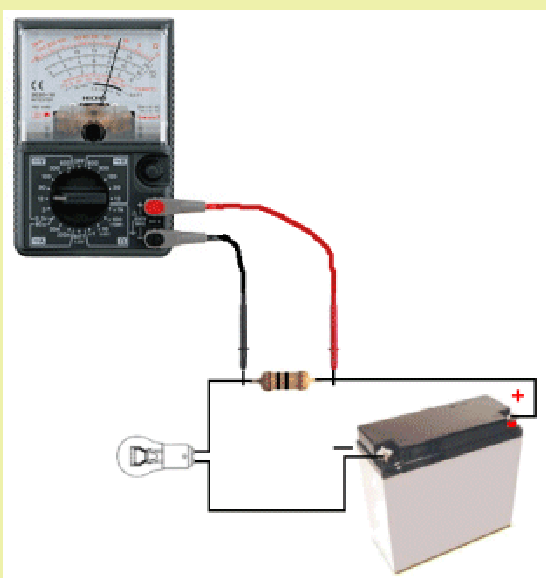


Fig 103g. Measuring the "sense resistor"

Its function is to produce a very small voltage across it and this voltage is detected by a circuit (basically a voltmeter (or milli voltmeter).
When a current flows though a resistor, a voltage is produced across the resistor. You can also say a

VOLTAGE DROP is produced across the resistor. If the resistor is exactly 1 ohm, a voltage of 1v will be produced across it when 1 amp is flowing or 1mV is produced for each 1mA of current. Using a 1 ohm resistor produces an easy conversion.
If the circuit is 24v or 50v, a loss of 1 volt will not be noticed.
But if the circuit has a lower voltage, (say 5v) the resistor will be need to be a lower value so the drop across the **sense resistor** does not upset the operation of the circuit.
The actual value of the resistor is not important for this discussion, It can be 1 ohm or 0.1 ohm.
The important point is to understand the function of a **Sense Resistor**.
In the circuit above, if the globe is replaced by a 20watt or 50watt, globe, the current through the sense resistor will increase. We measure the voltage (in millivolts) across the resistor and we convert the value into CURRENT. This is a CURRENT to VOLTAGE CONVERSION.
A transistor can be used as a CURRENT TO VOLTAGE detector. **Fig 103h** shows a 1 ohm sense resistor connected to a transistor. When the circuit is turned ON, the charging current (the current flowing into the battery) will be high and when the voltage across the **sense resistor** reaches 0.65v, the transistor turns ON and the voltage on the collector reduces. This turns on the red LED and reduces the voltage on the ADJ terminal of the LM317T regulator and the regulator outputs a lower current to the batter. This is how the circuit limits the charging current. The resistor is **converting** the current flowing through the circuit (and into the battery) into a voltage, and the transistor detects the voltage. The transistor is not detecting or measuring the current. It has absolutely no idea of the amount of current flowing. It is detecting the voltage across the resistor. The resistor is performing the **CURRENT to VOLTAGE** conversion.

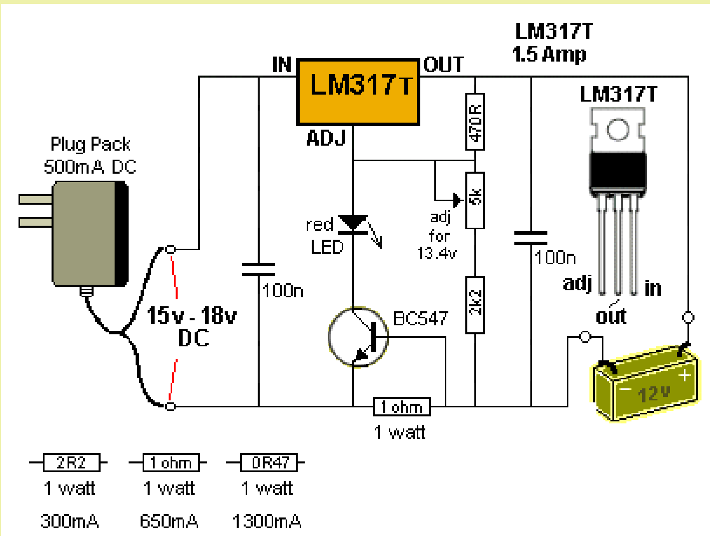


Fig 103h. The 1ohm Sense Resistor.

SQUEALING, BUZZING, OSCILLATING, and MOTOR-BOATING

We have studied **POSITIVE FEEDBACK** and the effect it produces. It turns an amplifier into an oscillator.
The following circuit will not work:

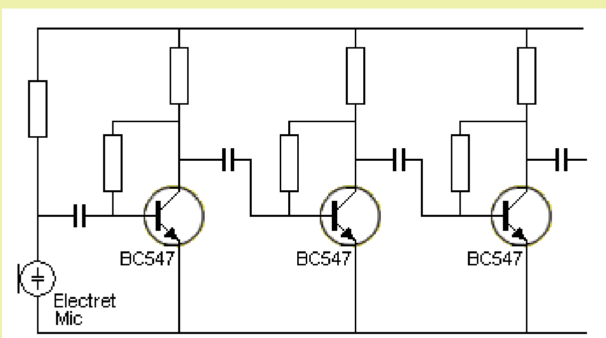


Fig 104a.

The three stages of amplification will produce so much gain that the circuit will self-oscillate. The output will be a "buzzing-sound" and the fault will be impossible to find because it comes from **within** the design of the circuit. The first thing you must do is add "power-supply decoupling."
The unwanted sound produced by the circuit is called **MOTOR-BOATING** and is generated in the "front-end" by very small noises or "disturbances" and amplified by the stages that follow.
Fig 104b shows where the noise starts. It can be produced by the electret microphone or by the noise in the junctions of the first transistor (due to current flowing in the collector-emitter circuit).

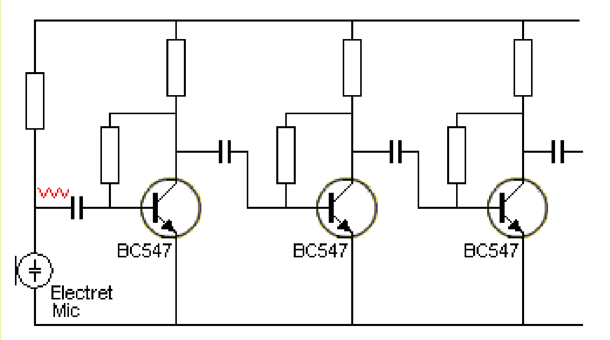


Fig 104b.

This waveform will be very small and almost impossible to detect via any test-equipment, but it will start in the first stage and pass through the coupling capacitor as shown in **Fig 104c**.
The next stage will amplify this "noise" and it will be amplified further by the following stages.
There will be some slight cancellations from the various stages as the signal will be "out-of-'phase" but the end result will be a "putt-putt-putt" or squealing from the output.
The general term for this is called MOTOR-BOATING and is due to the high gain of the circuit.
The noise will appear on the power rail and get passed to the front-end where it will be amplified more.

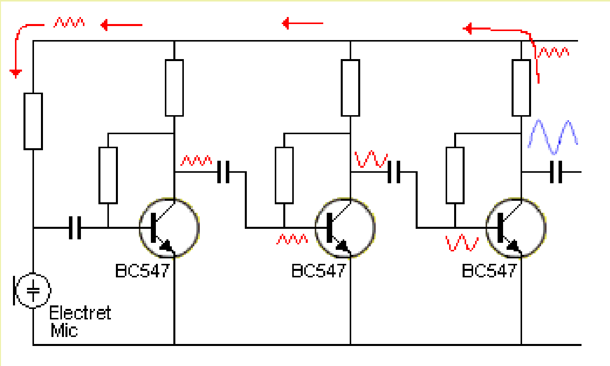


Fig 104c. The positive feedback loop producing "Motor-boating"

This effect can be reduce and eliminated by a term called **DECOUPLING**.
Decoupling is achieved by adding capacitors [electrolytics] (and resistors) across the power rails so that each stage is effectively powered by a separate supply.
Adding an electrolytic can sometimes make a big difference and sometimes it will make no difference.
It all depends where it is connected and the value.

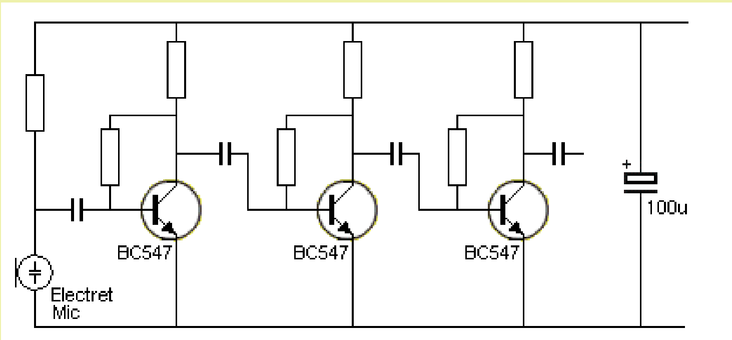


Fig 104d.

Fig 104d shows an electrolytic connected across the power rails. This is called **DECOUPLING THE POWER RAILS** and effectively tightens up the power rails so that any noise on the positive rail is removed.
But, as you can see, the power rails extend to the first transistor and although the rails may be "tight" near the battery they can "move" near the first stage.
This is due to the wiring between the stages or the tracks on the PC board. That's why an electrolytic across the battery may have little effect on removing our motor-boating problem.

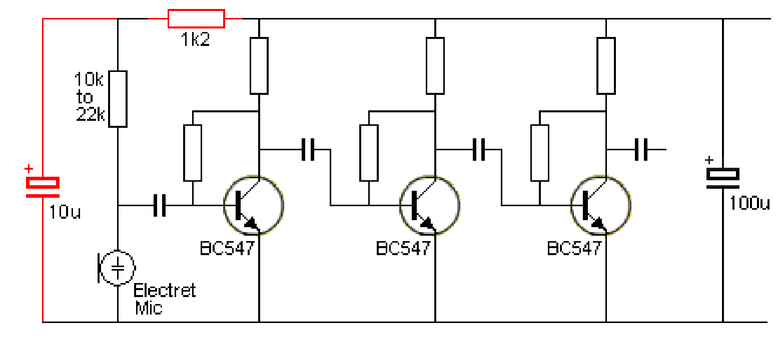


Fig 104e.

Fig 104e shows an electrolytic connected across the supply that feeds the electret microphone and 1k2 resistor to separate the supply we have just created, from the main supply rail.
We have effectively created a separate power supply. It is fed by a 1k2 and kept "tight" by the 10u capacitor.
The electrolytic does not have to be a high value because the electret mic takes very little current and the voltage-waveform (the AC signal) produced by the microphone is very small (about 20mV).
These two items **very effectively** decouple the microphone from the supply rails so the microphone has its own supply. The 1k2 resistor does most of the "separation." The voltage-drop across it will be very small and it will not affect the operation of the circuit, but the small voltage-drop will prevent any noise on the power rails being fed to the microphone via the 10k resistor.

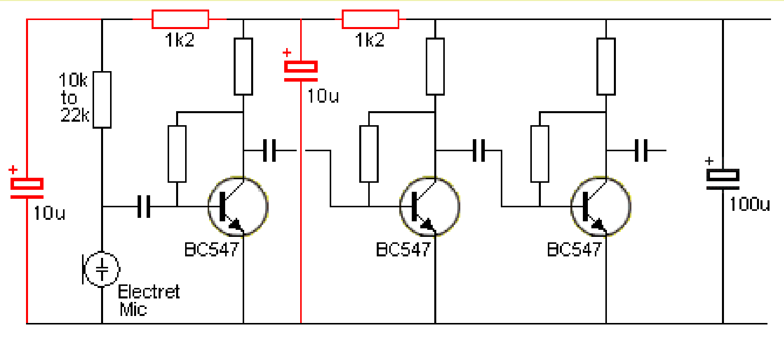


Fig 104f.

To remove any slight motor-boating problems (if they still exist); a power-supply filter (called power-supply decoupling) made up of a 1k2 and 10u can be placed after the first amplifier stage as shown in **Fig 104f**.
By selecting the value of capacitance and resistance, this arrangement will remove almost all motor-boating problems. It is a very-effective form of suppression.
Decoupling is most-effective on the pre-amplifier stages, however every circuit is different and these two components only deal with the low-frequency motor-boating type of instability. Some circuits also produce high-frequency oscillations (about 1MHz) and these need removing by a different value of capacitor-feedback.

BREAKDOWN and ZENER MODE

There are two conditions or states where a transistor can be instantly damaged. This is due to voltage applied in the wrong direction or the application of voltage that is higher than the rating of the transistor.
Voltage will kill a transistor faster than excess current.
A high voltage spike can damage a transistor instantly.
However if the excess voltage does not have enough current to damage the transistor, it will recover and we can use this feature in a circuit.
Breakdown and zener mode are different.
In **breakdown mode**, suppose we have a transistor that has a specification of 85v for the voltage it will withstand between the collector and emitter as shown in Fig 104g:

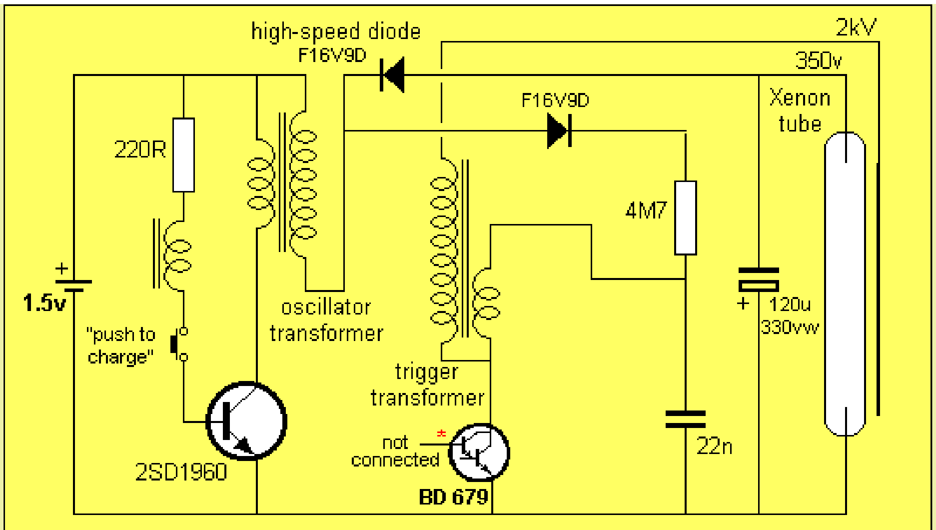


Fig 104g **XENON FLASHER - FLASH CIRCUIT**

It will "resist" a voltage of 85v and this voltage will appear across the collector-emitter leads. When the voltage increases to 86v, 87v ... the transistor will suddenly breakdown and only a few volts will appear across it. This fires the trigger transformer in the circuit above.
If the current is very small, the transistor will not be damaged and when the voltage is removed and a lower voltage applied, it will operate as an undamaged device.

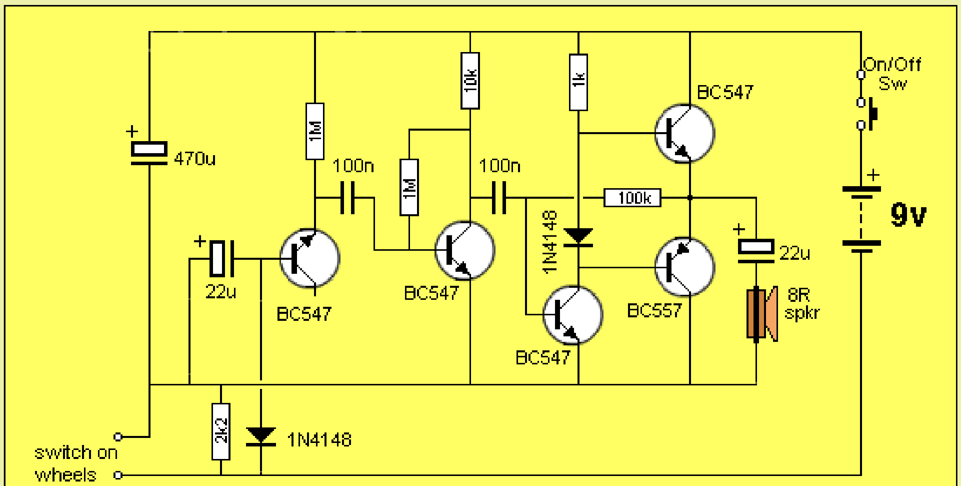
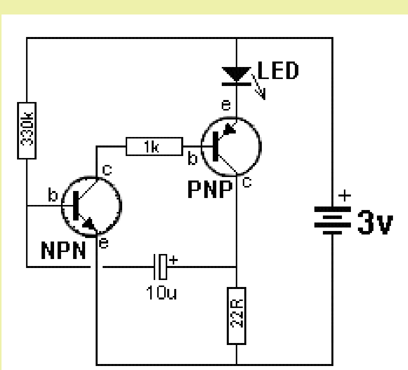


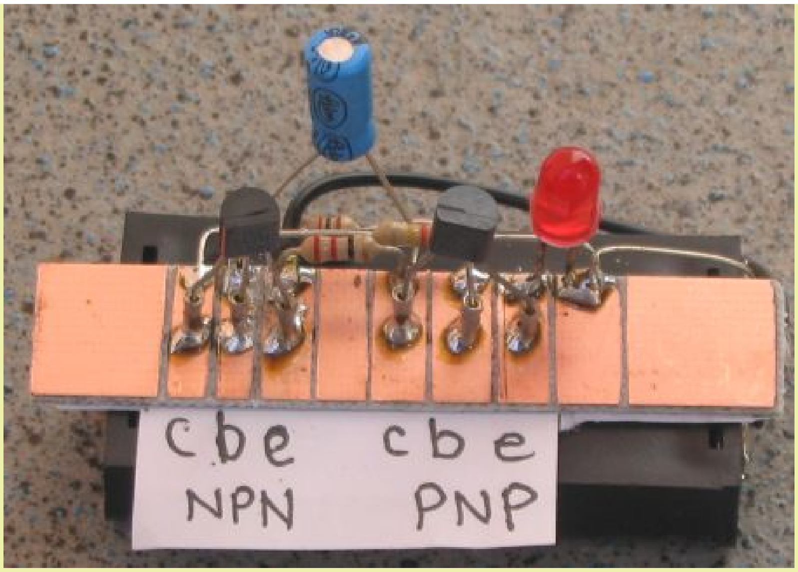
Fig 104h **STEAM ENGINE SIMULATOR**

In **zener mode**, the base-emitter junction is connected to a voltage higher than 9v via a resistor. The junction will breakdown and a voltage of about 7v will appear across the base-emitter leads and the excess voltage will be dropped across the resistor.
The zener-effect or zener mode can be used to produce white noise or a 7v zener reference. **Fig 104h** shows the first transistor with the base-emitter junction reverse-biased to produce a "noisy zener" via the 1M feeder resistor. The noise is picked off via the 100n and amplified by the remainder of the circuit.

TRANSISTOR TESTER

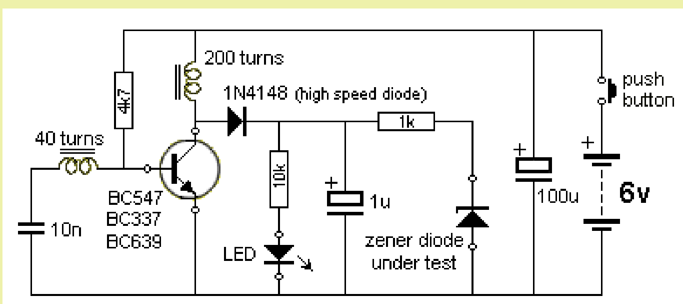


This circuit is basically a high gain amplifier with feedback that causes the LED to flash at a rate determined by the 10u and 330k resistor.
Remove one of the transistors and insert the unknown transistor. When it is NPN with the pins as shown in the photo, the LED will flash.
The circuit will also test PNP transistors. To turn the unit off, remove one of the transistors.



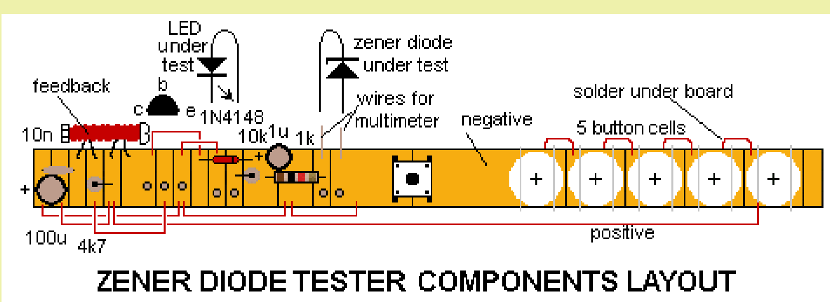
ZENER TESTER

The maximum voltage a transistor can withstand is called the ZENER VOLTAGE of the transistor.
It is Vce - the voltage between (across) collector and emitter. It is also the maximum supply voltage or circuit voltage or the voltage generated by an inductor in the collector-circuit and can be tested via the following circuit. This circuit will also test ZENER DIODES and LEDs.



TRANSISTOR and ZENER TESTER CIRCUIT

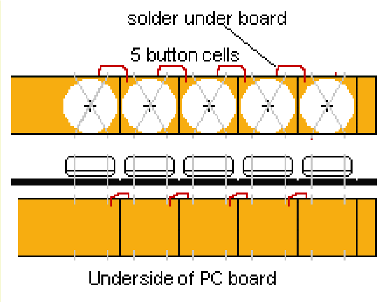
The circuit is a **flyback oscillator**. This type of oscillator energises an inductor then turns off very quickly and the magnetic field (flux) produced by the inductor collapses and produces a very high voltage in the opposite direction. The maximum voltage produced by the circuit depends on the "maximum voltage capability" of the transistor.
The voltage produced by the inductor is over 120v but the transistor will zener at a voltage lower than this and thus the output voltage will be determined by the characteristic of the transistor.
A diode on the output of the inductor passes this high-voltage-spike to a 1u electrolytic, which stores the energy and provides a high voltage output.
The circuit will test transistors up to 120v and zeners up to the voltage produced by the transistor.
The project is built on a strip of PC board cut into lands with a file or saw. The following diagrams shows the parts placement and connecting the 5 button cells to the board.
The project can be built in an evening and added to your TEST EQUIPMENT.



ZENER DIODE TESTER COMPONENTS LAYOUT

TESTING A TRANSISTOR

When testing a transistor, fit it into the pins marked C B E. If you have a LED connected to the LED terminals, it will glow. If you remove the LED and measure the voltage across the 1u electrolytic, it will provide the maximum working voltage for the transistor.

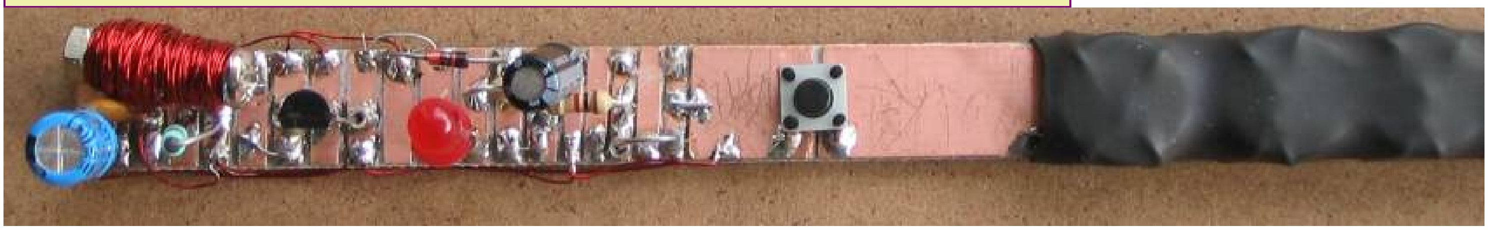


TESTING A ZENER

When testing a zener, place it in the pins provided. If the zener is around the wrong way, the voltage across it will be less than 1v.
When it is placed correctly, you can read the zener voltage with a high impedance multimeter such as a digital meter.

TESTING A LED

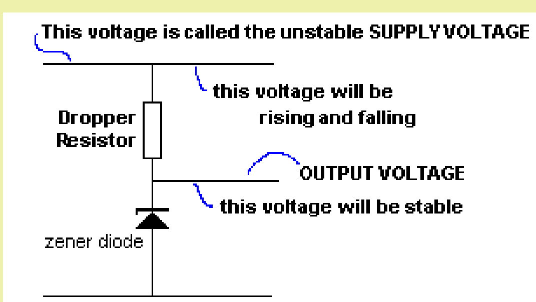
When testing a LED, fit it into the pins for the LED with the cathode lead (the shorter lead) to the left. It will glow very dim because the dropper resistor is very high and only allows 4 - 6mA to flow.
This will give you a good idea of the relative brightness of a LED when compared to others in a batch.



THE TRANSISTOR & ZENER REGULATOR

A transistor can be used to amplify the characteristics of a zener. You can also say the transistor is a **BUFFER** or **EMITTER-FOLLOWER**. It is another example of the transistor as an **AMPLIFIER** - a **DC AMPLIFIER** - indicating it amplifies the "steady-state" conditions provided by a zener diode.
We will start with the simple **Zener Regulator** circuit, then add the transistor amplifier. After that, we will remove the zener and add another transistor to improve the smoothness of the output waveform.

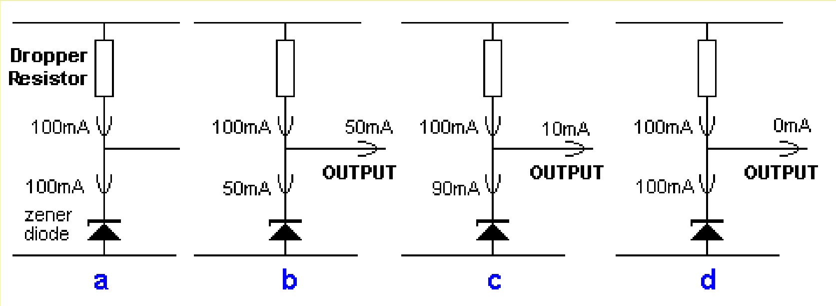
A simple zener regulator circuit is very wasteful however it is the basis for creating a stable output voltage from a voltage that may be rising and falling a considerable amount.
The following circuit shows a simple zener regulator:



A Zener Regulator Circuit

A **Zener Regulator Circuit** consists of a zener and a resistor. The resistor is called a **Dropper Resistor** and it is designed to limit the **CURRENT**. It is not designed to limit the VOLTAGE. The zener diode performs the task of limiting or SETTING the voltage on the output.
The current through the Dropper Resistor will be shared between the zener diode and the LOAD (on the output of the circuit). These two items may or may not share the current equally, and the amount of share will depend on the value of the LOAD. We can also say the Dropper Resistor is a **CURRENT LIMITER**. If is is not included, a 12v zener connected to a 15v supply would draw (or take) a very high current and "burn out."

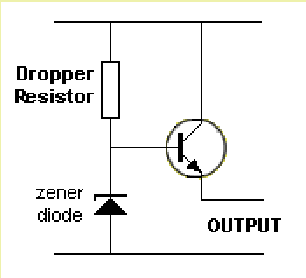
Here's the important fact about the current-sharing between the zener and load:
Suppose the SUPPLY VOLTAGE is fixed.
Here's an example of how the zener diode works:
Suppose we select a resistor so that 100mA flows through the zener when no load is present. Fig (a)
When the load takes 50mA, the zener takes 50mA. Fig (b)
When the load takes 90mA, the zener takes 10mA. Fig (c)
When the load takes 100mA the zener takes 0mA. Fig (d)



Current-sharing between the zener and output

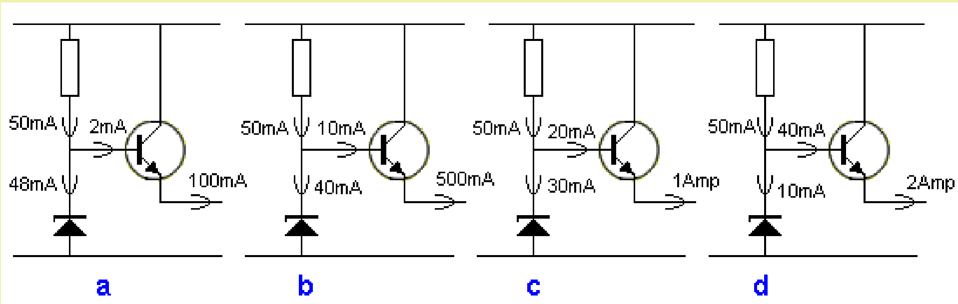
Up to this point the circuit works perfectly. Even though the zener takes 0mA, the circuit is operating perfectly and the output is smooth. If the load tries to take 101mA, the output voltage will DROP.
This is point at which the circuit is said to FALL OUT OF REGULATION.
The load (the OUTPUT) can take more the 102mA and the output voltage will drop further, but we are interested in the range where the output voltage is STABLE (fixed).
In this example, the current though the Dropper Resistor is ALWAYS 100mA. The current is then split (or shared) between the zener diode and the LOAD.
This feature is always the case with a zener diode regulator.
100mA is always flowing though the Dropper Resistor and if the load is taking only 10mA, this type of regulator is very inefficient.
When the supply rises, the current though the Dropper Resistor will increase. When the Supply falls, the current through the Dropper Resistor will decrease. During this time the output voltage of the circuit will remain constant providing the current though the zener is always at least a few mA and the maximum value does not allow the zener to get too hot. If the zener gets too hot it may fail.

The efficiency of the **ZENER REGULATOR** can be improved by adding a transistor. The transistor is an amplifier. A **CURRENT AMPLIFIER**. (also called a DC amplifier)
This type of circuit is sometimes called a **SUPER ZENER or AMPLIFIED ZENER**. The transistor is connected as an emitter-follower as shown in the following diagram:



An emitter-follower transistor

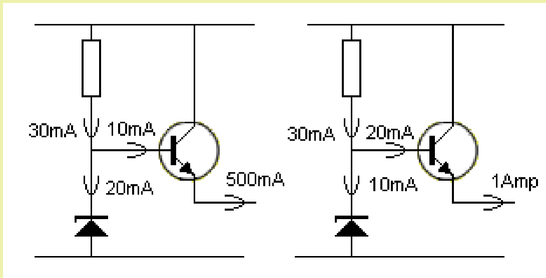
If the transistor has an amplification-factor of 50, it will require 2mA (into the base) for each 100mA delivered to the output.
This means our Zener Regulator only needs to deliver 2mA and the output can deliver 100mA. The emitter-follower transistor must be a POWER TRANSISTOR.
Here are some examples from 100mA to 2Amp:



The transistor has a gain of 50

In the circuits above, the output current can range from 100mA to 2Amp. The zener will pass 48mA when the load is 100mA and drop to 10mA when the load is 2Amp.

If the output requirement is only from 500mA to 1Amp, the value of the dropper resistor can be changed so the zener takes 20mA when 500mA output current is required and 10mA when 1 amp is required.



When designing this type of circuit, the zener is allowed to take 10mA when the maximum current is required. The 10mA is about the minimum current for a 12v (300mW to 500mW) zener to keep it in conduction. The actual minimum value depends on the wattage of the zener and also its voltage. You will need to look at the specification sheet for the zener you are using.

The term "keep it in conduction" means this: Suppose we have a 12v zener and dropper resistor connected in series. As the voltage (the SUPPLY VOLTAGE) on the combination is reduced, the current through the zener reduces. If you supply the combination with 11.5v, the zener will "fall out of conduction" and it will appear like a very high value resistor or even an infinite resistance.
In the transistor / zener regulator circuit above, if the current taken by the load increases above 1Amp, the current into the base increases and when it reaches 30mA, the zener receives NO CURRENT.
Any further increase in current by the load causes more current to flow through the Dropper Resistor and the voltage across this resistor will increase. This will lower the voltage on the base and also lower the voltage on the emitter. At this point the zener has dropped out of regulation.

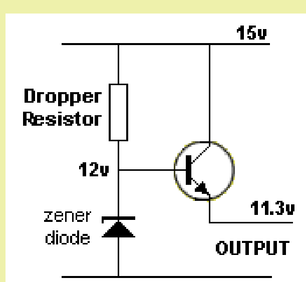
If the transistor has a gain of 50, the maximum output current is divided by 50 and this gives the base current of 20mA.
Add 20mA to 10mA to obtain the current through the Dropper Resistor.
The value of resistance for the Dropper Resistor is obtained by the formula:

$$R = \frac{\text{voltage of supply - voltage of zener}}{\text{current through Dropper Resistor}}$$

Suppose the supply is 15v and the zener is 12v . The value of the Dropper Resistor is:

$$R = \frac{15v - 12v}{0.03\text{ Amp}}$$
$$= \frac{3}{0.03} \quad = 100R$$

The output voltage is 0.7v less than the voltage of the zener.
The following diagram shows an example of the voltages on a typical regulator circuit:

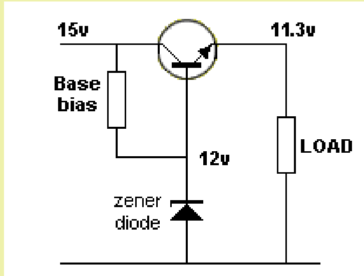


The voltages on the regulator circuit

SUMMARY

A power transistor can be used to amplify the characteristics of a zener. That's what the circuit above is doing. The circuit is sometimes drawn as shown in the following diagram. It is more difficult to see exactly how the circuit is operating, but this is how it is drawn in many projects. By drawing the circuit as shown above, you can see the voltages on each section of the circuit and you can't make a mistake. One "circuit engineer" said the output was 1.2v above the input voltage. But when you draw the circuit as suggested, you can clearly see this

is not possible.
That's why the layout of the circuit is MOST IMPORTANT.



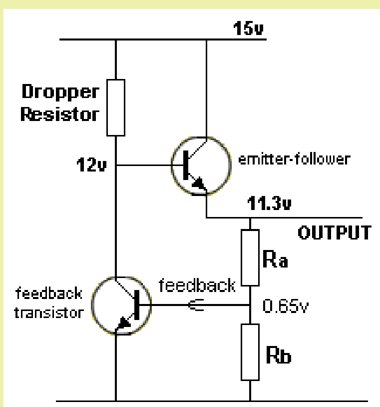
The regulator circuit re-drawn

IMPROVING THE SMOOTHNESS OF THE OUTPUT

The quality of the output (meaning the smoothness of the output) of a regulator - also called the smoothness of a POWER SUPPLY - can be improved by adding a transistor that detects any increase or decrease in the the output voltage and produces an opposing signal to counteract the rise or fall. The end result is very smooth DC.
The action of this transistor is called **NEGATIVE FEEDBACK**.
In the regulator circuit above (and the circuit with the transistor amplifier), the output is not being monitored and if the zener is noisy, (in other words it breaks down in an irregular mode and creates ripple) there is no feature to detect the changes, and reduce them.

The following circuit uses a transistor to detect the output voltage and provide a feedback signal (feedback voltage) that will eliminate the ripple. It is called a **FEEDBACK SIGNAL** or simply **FEEDBACK**.
The zener diode can be removed and two resistors used to monitor the output voltage with the voltage at their join being passed to the feedback transistor.
The base-emitter voltage of the transistor replaces the zener diode as a "reference" and the transistor turns into a zener diode with the "zener reference" appearing between the collector and emitter.

The following circuit shows the feedback transistor replaces the zener diode in the circuit above and two VOLTAGE DIVIDER resistors on the output are connected to the base of the feedback transistor.



When the circuit turns ON, the output voltage rises until the voltage at the join of the resistors reaches 0.65v. The feedback transistor starts to turn ON and prevents the base of the emitter-follower transistor rising above 12v. This creates an output voltage of 11.3v.
Any reduction in the output voltage will turn off the feedback transistor a very small amount and it will allow the voltage on the base of the emitter-follower transistor to rise and this will increases the output voltage.
The feedback transistor is also called an **ELECTRONIC FILTER**.
It has an effect equal to the gain of the transistor (approx 100) on smoothing the output.

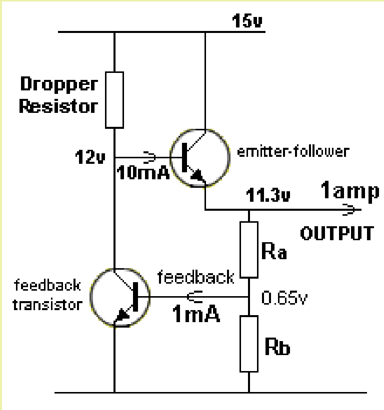
HOW DO YOU WORK OUT THE RESISTOR VALUES?

For the resistor values for the following circuit, we start with Ra and Rb.
The output current is 1amp and the transistor can handle more than 2 amps, so the gain at 1amp is 100. The feedback transistor also has a gain of 100, but this is not important for these calculations.
Starting with Ra and Rb, we allow 10mA to flow though this voltage divider so the stability of the circuit is very high.
The resistance of Rb = 0.65/.009 = 72 ohms.
The resistance of Ra = 10.65/0.01 = 1.065k

The resistance of the dropper resistor = 3/0.01 = 300 ohms

The circuit turns on via the 300 ohm dropper resistor pulling the base UP. As the output voltage rises, a point is reached where the voltage into the feedback transistor reaches 0.65v and the transistor turn ON. **It turns into**

a resistor and the join of this "resistor" and the Dropper Resistor create a voltage of exactly 12v. At this point the circuit becomes stable.



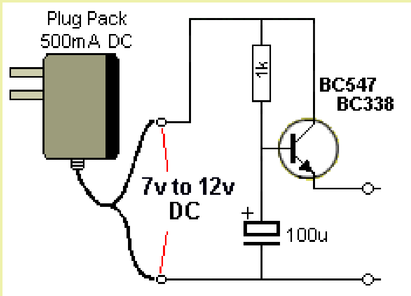
Ra and Rb can be any values providing the ratio is 72:1065. For instance, the values can be 144:2130 or 108:1597 (where the values are increased by 50%).
The value of the **Dropper Resistor** can be any value **less than** 300R and although this will theoretically allow more current to enter the base of the emitter-follower transistor, the transistor will not take any more current than it requires to create the necessary collector-emitter current (and thus the exact voltage of 12v at the collector).

TRANSISTOR GAIN

As the current through a transistor increases, the gain of the transistor decreases. This means a transistor may have a gain of 100 when a small current is flowing thorough the collector-emitter circuit, but as the current increases to say say 50% (of the maximum allowed for the device), the gain may decrease to 50.
As the current increases to a maximum, the gain may decrease to 20.
All these values are variable and we cannot specify any exact values, so you have to remember to takes these facts into account when designing a circuit.
That's why a transistor with a maximum collector current of 4 amps is chosen for a circuit requiring 1 amp. You are not over-stressing the transistor and it will provide a gain of about 100.

THE ELECTRONIC FILTER

Here is a simple circuit to reduce the ripple from a power supply by a factor of about 100. This means a 20mV ripple will be 0.2uV and will not be noticed. This is important when you are powering an FM bug from a plug pack. The background hum is annoying and very difficult to remove with electrolytics. This circuit is the answer. The 1k and 100u form a filter that makes the 100u **one hundred times** more effective than if placed directly on the supply-line. The transistor detects the voltage on the base and also detects the very small ripple.
As current is taken by the load, about 100th of this current is required by the base and if the load current is 100mA, the current into the base will be 1mA and one volt will be dropped across the 1k resistor.
The circuit is suitable for up to 100mA. A power transistor can be used, but the 1k will have to be reduced to 220R for 500mA output. The output of the circuit is about 2v less than the output of the plug pack.
By adding a zener across the electro, the output voltage will remain much more constant (fixed). If a zener is not added, the output voltage will drop as the current increases due to a factor called REGULATION. This is the inability of the small transformer to provide a constant voltage. The addition of the 3 components only reduces the RIPPLE portion of the voltage - and does not change the fact that the voltage will droop when current is increased. It requires a zener to fix this problem.



An ELECTRONIC FILTER

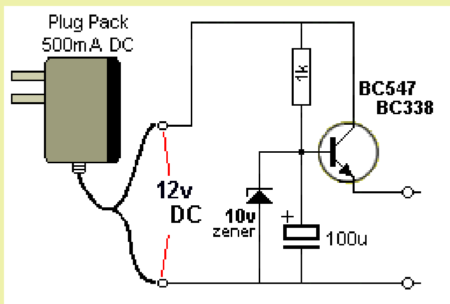
THE ELECTROLYTIC AS A FILTER

The circuit above shows an electrolytic used to remove the ripple from a power supply.
1. How does the electrolytic reduce the ripple?
2. Why do you need a larger capacity electrolytic for a higher current?

1. The electrolytic is just like a rechargeable battery.

When the voltage is higher than normal, the electrolytic gets charged and this puts an additional load on the supply. Some of the extra voltage (as well as the current being delivered by the supply-voltage) is passed to the electrolytic as energy and the supply voltage is reduced slightly.
When the supply-voltage drops, the voltage contained in the electrolytic is slightly higher than the supply and it delivers energy. This prevents the supply-voltage dipping too much.
You can see the electrolytic is receiving and delivering only a very small amount of its stored energy and that's why its value must be very large (about 1,000u for each amp delivered by the power supply). This is because the electrolytic has to have a large ability to store a lot of energy when the voltage rise and falls only a very small amount.
2. When the current is a large value (say 1 amp), the energy contained in a few millivolts and a current of 1 amp, is a very large and thus a high capacity electrolytic is needed.

When an electrolytic is placed across a power rail, it smoothes the voltage by BRUTE FORCE. A large electrolytic will produce more smoothing.
But when the electrolytic is connected to the supply via a resistor, the electrolytic will take time to charge when the voltage rises and time to discharge when the voltage fall.
This means the ripple on the electro will be much less than the ripple on the power rail.
Depending on the value of the resistor and electro, it may be 1/100th of the ripple on the supply.
The transistor detects this improved voltage and allows a high current to pass to the load.



The zener improves the circuit enormously

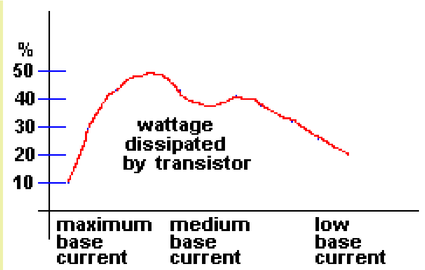
The addition of a zener diode improves the output of the circuit enormously. When the circuit delivers current, the voltage will "sag" and sometimes the voltage will drop to 11v. If we include a zener, we will only be delivering a voltage of 10v minus 0.7v = 9.3v and this voltage will will NEVER have any ripple (in it). Thus this voltage will never have any "hum."

THE TRANSISTOR AS A LOAD

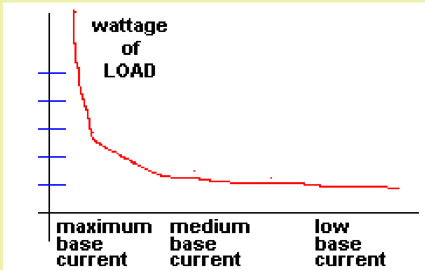
This might seem an unusual topic but many circuits use a transistor as a LOAD or VARIABLE LOAD or partial load (in conjunction with a LOAD RESISTOR) to dissipate (remove - take away) power - to prevent another item (such as battery) being overcharged or a delicate device getting too hot.
We are talking about wasting energy or losing energy in the form of heat to prevent another item in a circuit getting too hot.
A power transistor such as 2N 3055 is ideal for this purpose however there are smaller power transistors for smaller losses.
We use the gain (amplification factor) of the transistor to provide this feature and by controlling the base current, the current though the collector-emitter terminals can be adjusted. In most cases the transistor is in series with a LOAD RESISTOR and the two items can be adjusted to remove unwanted energy.
In addition, the percentage dissipated by the transistor compared to the load resistor depends on the base current of the transistor.
This is quite a complex topic as the losses can be adjusted to any percentage, irrespective of the supply voltage.

This is sometimes called an **ELECTRONIC LOAD** or **ACTIVE LOAD** because the effectiveness in dissipating heat can be controlled by current entering the base of the transistor.
A POWER RESISTOR (by itself) is called A DUMMY LOAD or STATIC LOAD. It's dissipation is fixed (providing the voltage of the supply is fixed).
Our discussion introduces a variable dissipation, controlled by the base current of a transistor.
This is another example of a transistor being used as an amplifier. The current into the base is amplified by the transistor to produce a current through the collector-emitter leads.
This current also flows through a LOAD RESISTOR and the resistor increases in temperature.
The loss in the transistor and resistor is calculated in terms of watts and when this is extended over a period of time, the result is energy - watt-hours. This energy is given off as heat instead of raising the temperature of a critical component in a circuit.

The following diagram shows the heat dissipated in the transistor when maximum, medium and low current flows into the base of the transistor:



When maximum base current is supplied to the transistor, it is turned ON fully and only about 10% of the total wattage is lost in the transistor. This means the total wattage of the load can be very high.
As the current is reduced, the wattage dissipated in the transistor increases to about 50%, then drops off.
The following diagram shows a large wattage will be dissipated in the resistor (and very little via the transistor) when maximum current is supplied to the base of the transistor, but as the base current is reduced, the size of the load must also be reduced because more of the load is dissipated in the transistor (and the transistor is the limiting factor).

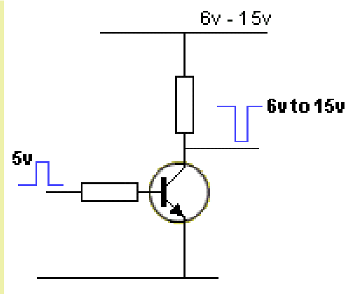


It is impossible to work out the "load sharing" between the transistor and resistor for any given base current because transistors from different batches have considerably different characteristics.
The diagrams we have provided show percentages but not the base current required to create the load sharing.
Even simulation software will produce false data as the actual characteristics of the transistor you are using will be unknown.
Rather than spending time on trying to work out the probable results via a software package, it is much easier to build the circuit and apply current to the base.
As you apply current into the base, you can monitor the current through the load via an ammeter and provided the transistor is correctly heatsinked, it will not overheat.
A 2N3055 will dissipate 115 watts using a very large heatsink. This gives a starting-point for the maximum wattage for the system.
When the transistor is turned on so it dissipates the same wattage as the resistor, the total losses for the system can be as high as 230 watts, but when the transistor is fully turned on, the system can handle about 1,0000 watts.
However the transistor must change very quickly from a state where it is not turned to a fully turned-on-state. (If not, the transistor will be damaged very quickly if it becomes partially turned on.)
In the fully-turned-ON state, the transistor is fully saturated and is dissipating only about 10% of the total load and the resistor is dissipating about 90%.

These are all points you need to know, when designing an **ACTIVE LOAD**.

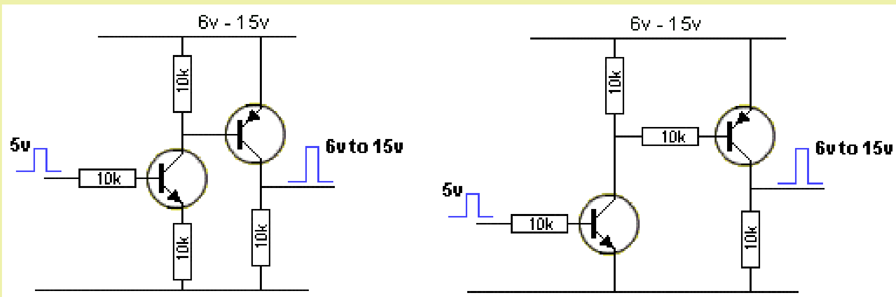
THE TRANSISTOR AS AN INVERTER

A transistor can be configured as an inverter - to change a signal (that moves from LOW to HIGH) into a signal that changes from HIGH to LOW.
This type of circuit can be used to transform a 0-5v signal into a 0-9v signal. This is called **VOLTAGE SHIFTING** or **LEVEL SHIFTING**. In this case, a LOW to HIGH (0-5v) signal is converted to a "HIGH to LOW" (0-9v) signal. The output changes when the base sees a voltage between 0.55v and 0.7v. The remaining input voltage is dropped across the base resistor. The output voltage will be initially HIGH and go LOW as soon as the input voltage reaches about 0.7v.



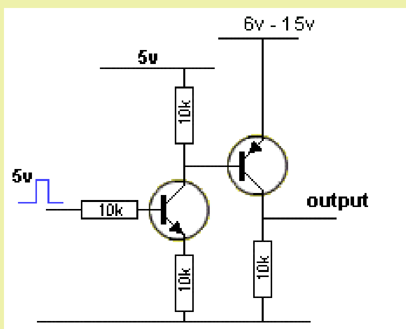
5v to 15v Inverter

A non-inversion circuit is shown in the following diagrams:



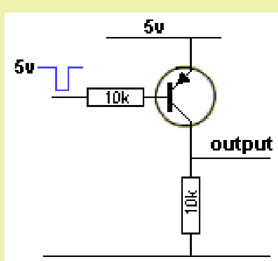
5v to 15v Non-Inverter

The following circuit does not work because the second transistor is never turned off. Both transistors MUST be connected to the high voltage rail.



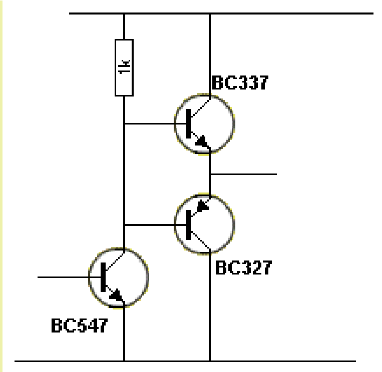
This circuit does not work

The following circuit converts a signal that starts as **5v HIGH** and goes **LOW**. During this signal transition, the output start with a **LOW** value and goes **HIGH**.



5v to 0v Inverter that produces 0v to 5v Output

The following circuit is a Push-Pull Inverter:



Push-Pull Inverter

All the circuits above convert an analogue signal or A DIGITAL SIGNAL into a digital signal. This is due to the gain of the transistor. In other words the output does not respond in a linear manner, (to the input voltage). The output changes when the input moves from a voltage of about 0.55v to about 0.7v. Input voltages below 0.55v have no effect and voltage above 0.7v do not affect the circuit as the circuit has already changed state.
One other characteristic of the circuit is this: It speeds up the waveform and removes noise from a noisy signal.

ADDING A TRANSFORMER

One of the most complex electrical/electronic components is the TRANSFORMER. It is the simplest component and yet it produces the most complex effects. A transformer is simply a coil of wire placed near another coil of wire. The results and effects will amaze you.
There are so many different effects, we could write an eBook.
In fact we will write a chapter on the subject, but firstly we will cover 5 things:
1. A single coil of wire is not a transformer but an inductor.
Without going into any complex mathematics, here is a fact you should know:
When an inductor is connected to a battery, the current does **not** flow though the turns immediately, but a few microseconds or milliseconds later. This is called **CURRENT LAG**. Don't ask why, it's just a fact.
But the most amazing thing is this: When the voltage is removed, the inductor produces a HIGHER output voltage IN THE REVERSE DIRECTION.
If the coil is wound on a cardboard former, the core (the centre of the coil) is air and the voltage (the reverse voltage) produced, may be twice the supply voltage. But if the core is steel or other magnetic material such as iron (stalloy) or ferrite (a special type of iron) the reverse voltage may be 100 times HIGHER or even 1,000 times HIGHER.
That's why a simple coil of wire is one of the most amazing things.
We can control the magnitude of this reverse voltage by adjusting the frequency and/or the speed at which we turn the voltage OFF.
Even though the inductor is not called a transformer, we are "transforming" a low voltage into a high voltage.
We are not getting "something for nothing." **Conservation of energy still applies**. We are transforming a low voltage at high current into a high voltage at low current. The watts **IN** equals the watts **OUT**.
When we add another winding, the two coils become a TRANSFORMER.
The first winding is called the **PRIMARY** and the second winding is called the **SECONDARY**.
We drive a transformer in a slightly different way to an inductor.
We deliver a rising and falling voltage to it slowly. This is called an AC delivery and although the letters "**AC**" mean Alternating Current, we really mean Alternating Voltage.
When we deliver a slowly rising and falling voltage, the primary does not produce the high reverse voltage discussed above but it does produce a **reverse voltage** that can be as high as 99.99% of the applied voltage. But this is getting away from the point we want to cover.
The secondary winding produces an exact copy of the voltage flowing into the primary and if you measure it on a piece of test equipment, it will follow the primary exactly (but slightly delayed). If you reverse the leads to the test equipment, the results will be a "mirror image." That's how we get a reverse voltage out of the transformer.
Here's the next valuable fact: The voltage from the secondary will be higher if the secondary has more turns or lower if the secondary has fewer turns than the primary.
If it has more turns, the transformer is called a **STEP-UP** transformer and if it has less turns the transformer is called a **STEP-DOWN** transformer.
Here's our last amazing fact:
If the secondary has less turns, the current from the secondary can be higher than the current in the primary.
But if the secondary has more turns, the current from the secondary will be less than the current in the primary.
With all these facts and capabilities, we can do incredible things with a transformer.
We forgot to mention one of the most beneficial uses for a transformer. The voltage on the primary is totally isolated from the secondary. In other words, the primary may have 110v or 230v on it and the secondary may have 12v. You can touch either lead of the 12v winding and any metal pipe and not get a shock. The transformer provides total isolation. But if you touch either end of the primary winding and a metal pipe you will be killed instantly.
That's one of the main uses for a transformer - to provide isolation from the "mains." The energy passes from the primary winding to the secondary via **magnetic flux** and the two windings are ISOLATED and INSULATED from each other.

A transformer can be smaller that a grain of rice to the size of a house and there are millions of different types. That's why they are so complex.

As soon as the eBook article is written, it will be included HERE.

A transformer is a complex item. It takes up a lot of space on a PC board and is expensive to make.
It is not added without a reason and a lot of thought.
Here are 8 reasons why a transformer is included in a project
1. To produce a voltage higher than the supply,
2. To produce a very low voltage,
3. To produce a high current,
4. To produce a sinewave wave,
5. To mix two different signals or frequencies,
6. To produce a feedback signal,
7. To produce a number of different, isolated voltages (and/or current),
8. To produce isolation. And many other reasons.

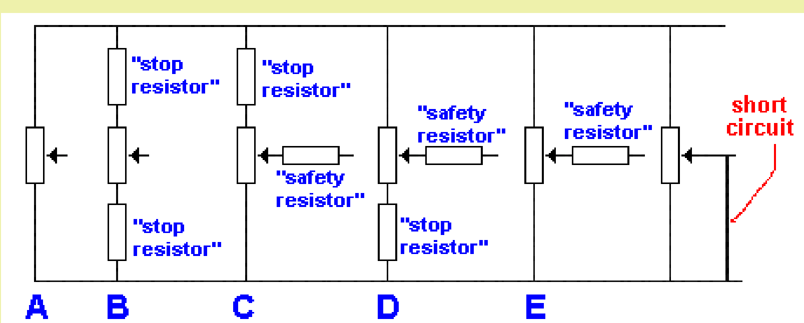
Driving a transformer is not like delivering current to a resistive load.
The primary winding of a transformer has a very small resistance but when it is delivered an increasing voltage, the magnetic flux (produced by the voltage) creates a voltage in the opposite direction that cuts the turns of the winding and this voltage opposes the incoming voltage.
This effectively makes the winding appear to be a higher resistance. When a transformer is delivering energy via the secondary winding, the "back-voltage" produced by the magnetic flux will be less and the input current (via the primary) will be higher.
A transformer is designed to receive an increasing and decreasing voltage. During this time it can deliver energy to the secondary.
But when the voltage rises and remains HIGH, the opposing voltage produced by the expanding magnetic flux ceases and input current increases considerably.

DESIGNING A TRANSFORMER

Designing a transformer is very difficult and complex. The easy approach is to buy a product that contains a circuit similar to your requirement and use the transformer.
It is very difficult to take a transformer apart as the laminations or the ferrite core is dipped or glued or sealed so the windings do not move.
In some cases you can buy laminations or ferrite cores (called pot cores) but there are many different types of materials and unless you know the composition of the material, the resulting transformer can be as low as 10% successful.
The other problem with taking a transformer apart is this:
Many transformers have an air-gap in the magnetic circuit to "remove" or "use-up" the magnetic flux created by the DC component of the input current.
If this air-gap is not maintained in its exact thickness, the new transformer will not be identical in performance to the original.
A transformer without an air gap must have "lapped surfaces" so the two halves of the core touch each other.
All these technicalities will be covered in the eBook.

THE POTENTIOMETER

A potentiometer is simply a resistor with the resistance-material exposed to a wiper.
The resistance-material is called a TRACK and it can be straight or curved. When the track is curved, we generally call it a "pot" (abbreviation for potentiometer) and the pot is rotated to increase or decrease the resistance. When the track is straight we call it a 10-turn pot. And a screw is available on the end of the pot.
Straight tracks are also available in pots called SLIDERS. All pot have the same symbol.
In most cases a pot is connected to a circuit with a resistor on one end or on the centre terminal (the "wiper") as shown in the following diagrams:



STOP RESISTOR and SAFETY RESISTOR

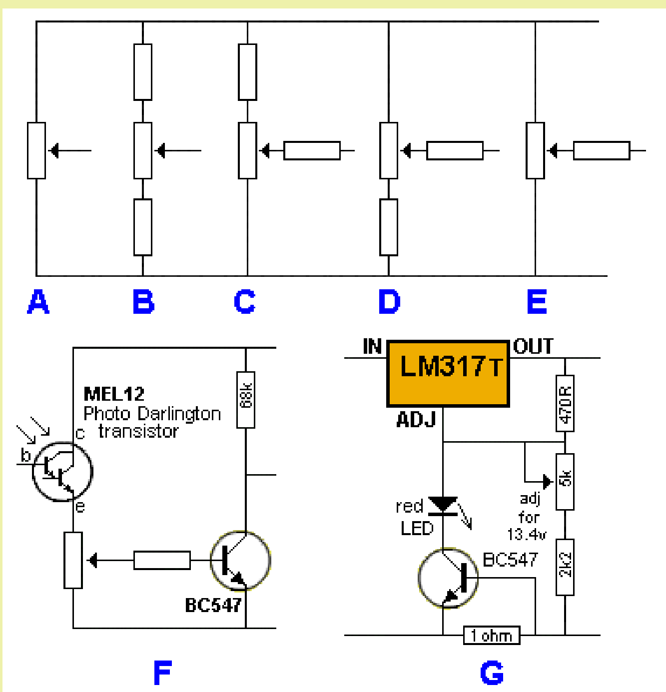
A resistor added to the top or bottom of the pot is called a **stop resistor**. It stops the pot reaching full rail voltage or 0v. A **safety resistor** is added to the wiper so the pot is not damaged when turned fully clockwise and the resistance of the output is low.
Fig A above shows a pot with no external resistors. The voltage on the wiper can be as high as rail voltage

or as low as 0v.
Fig B shows a pot with a resistor to positive rail and one to 0v rail. The voltage on the wiper will not be as high as rail voltage or as low as 0v. By selecting a pot with a particular value and resistors for the top and bottom, maximum and minimum voltages can be set.
Fig C shows a pot with a top resistor. This sets a maximum voltage, while the minimum will be 0v.
Fig D shows a pot with a bottom resistor. This sets a minimum voltage, while the maximum will be rail voltage.
Fig E shows a pot with a resistor on the wiper. The allows the voltage on the wiper to be as high as rail voltage or as low as 0v. The resistor is called a "safety resistor." It prevents the pot being damaged if the output becomes shorted as shown in the last diagram.
If the pot in the last diagram is turned fully clockwise, the wiper will each rail voltage. If the wiper is connected to a low resistance, a high current will flow and damage the pot.
A "safety resistor" will reduce the high current.

There are three reasons why a pot is included in a circuit.
1. To "pick off" a voltage.
2. To deliver a current
3. To "pick off" an amplitude.

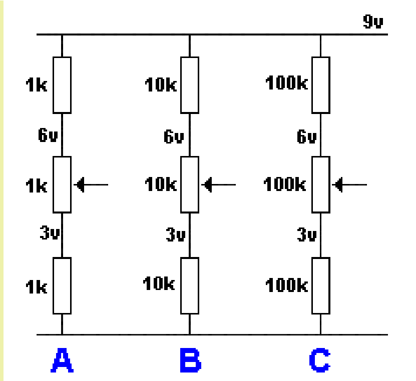
"PICKING OFF" A VOLTAGE

The following diagrams show a pot "picking off" a voltage. The pot values have not been shown because we are dealing with the concept of picking off a voltage.
In actual fact the pot will be delivering a current (via the wiper) to the circuit connected to the wiper, but to separate the functions of a pot, we have identified this function as PICKING OFF A VOLTAGE.
The main difference between **Picking Off A Voltage** and **Delivering A Current**, is the value of the pot.
The resistance of a pot for **Picking Off A Voltage** is generally a high value. The term "HIGH VALUE" is relative to the situation.
In Figs F and G you can see the SAFETY RESISTOR and STOP RESISTORS.
The wiper in figure F picks off a voltage from the pot. The pot is the load resistor for the MEL12 Photo Darlington Transistor and although it is delivering a small current to the base of the transistor, this current is very low and that's why we refer to the pot as "picking off a voltage."
The safety resistor in Fig F could be replaced with a stop resistor above the pot.
This change can be done in some circuits and you have to build the circuit to determine if the change can be made.

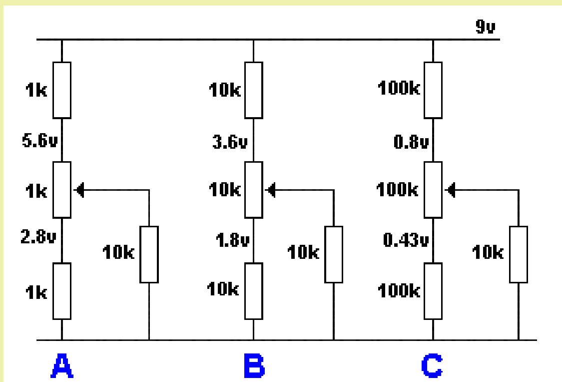


POT RESISTANCE

The resistance of a pot is selected from one of the following values: 100R, 500R, 1k, 5k, 10k, 50k 100k, 1M and 2M.
In most cases you will copy a circuit and use the same value for the pot.
Working out the value is quite a complex task.
Here are three different circuits. The voltage on the top and bottom of the pot is the same, but the value of the resistances is different.
The first circuit is classified as LOW IMPEDANCE. The second is MEDIUM IMPEDANCE and the third is HIGH IMPEDANCE.



The output from each pot will range from 3v to 6v. So, why different values of resistors?
The reason is to keep the current through the pot as low as possible.
The current through the resistors is WASTED CURRENT. If a project is battery operated, wasted current is a problem.
The resistance of the load on the wiper also determines the value of the pot.
Let's look at a 10k load connected to the wiper:

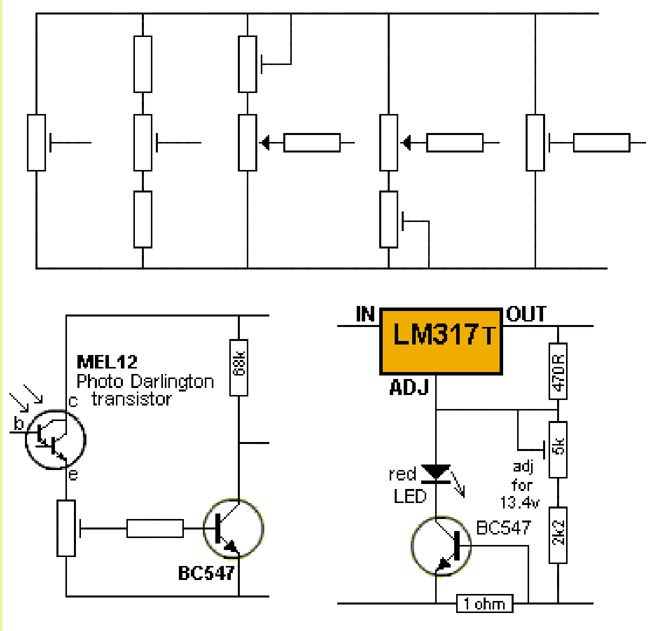


The voltage on the top and bottom of the pot changes when a load is added.
In circuit A, the voltage reduces a small amount as the 10k load has little effect on the low- value resistance of the pot and resistors.
In circuit B, the 10k load has a larger effect on the voltages.
In circuit C the 10k load has a major effect on the voltages.

This means it is necessary to choose values that are acceptable for minimum current through the pot as well as creating the required voltage on the top of the pot.

TRIM POT

A trim pot is simply a pot without a shaft. It usually has a screw-driver slot and is adjusted once in the life of a circuit. It is usually small in size and can be any resistance value to suit the circuit.
It can be connected as the only pot in a circuit or used in conjunction with an ordinary pot to set a particular value or "setting."
It is identified in a circuit as follows:

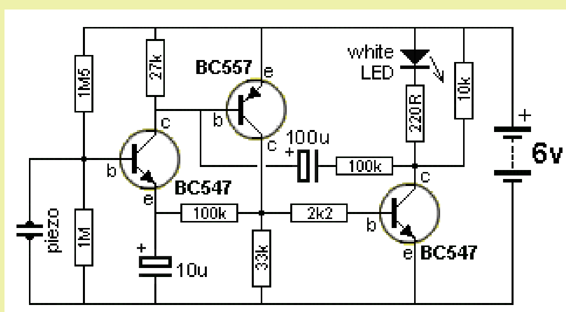


TRIM POTS can be used to trim the value of a POT

THE VOX - Voice Operated Switch

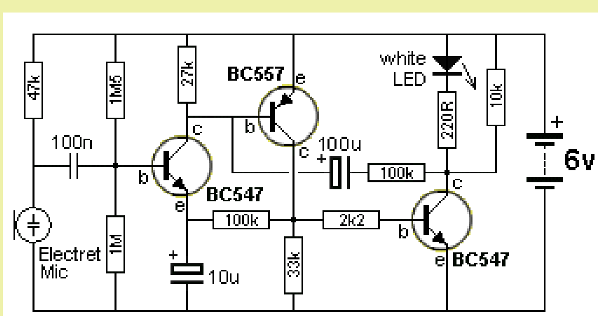
Basically, a VOX circuit is a very high gain amplifier that detects faint sounds and turns on a relay.
Here are a number of voice-operated (sound operated) circuits that turn on a relay or activate a device.
In general, a VOX circuit keeps the relay activated for a short time between sounds so the device remains constantly illuminated or activated.

The first circuit is a CLAP SWITCH. The LED illuminates for 15 seconds after the sound of a clap. For full details of the circuit see [Fig 71acd](#).



CLAP SWITCH USING PIEZO DIAPHRAGM PICK-UP

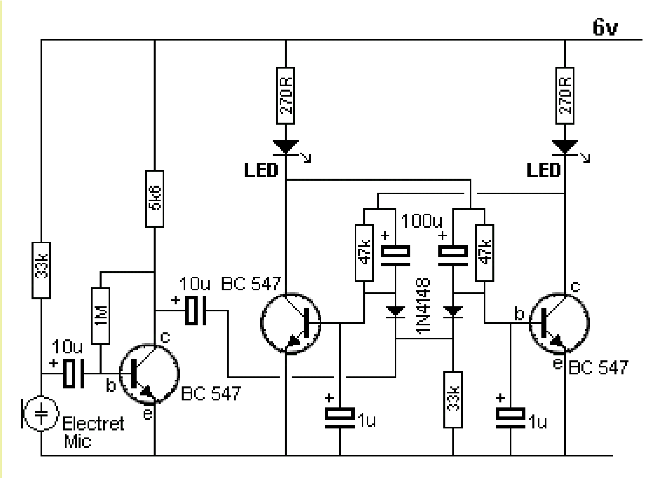
The circuit above takes about 20uA when "sitting around." That's because the piezo diaphragm does not require any current.
The same circuit can use an electret microphone for the input but the idle current rises to 200uA.



CLAP SWITCH USING ELECTRET MICROPHONE

Both circuits detect a clap but neither will detect faint noises or talking.
The circuits do not keep the LED illuminated constantly but only illuminate for 10 - 15 seconds and turn off for 10 - 15 seconds.

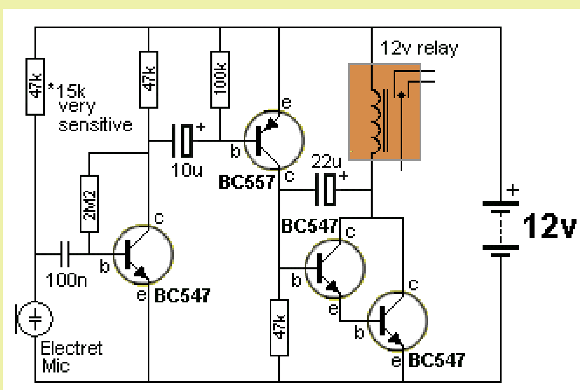
This circuit toggles the LEDs each time it detects a clap or tap or short whistle.



CLAP SWITCH TOGGLES THE 2 LEDS

The second 10u is charged via the 5k6 and 33k and when a sound is detected, the negative excursion of the waveform takes the positive end of the 10u towards the 0v rail. The negative end of the 10u will actually go below 0v and this will pull the two 1N4148 diodes so the anode ends will have near to zero volts on them.
As the voltage drops, the transistor in the bi-stable circuit that is turned on, will have 0.6v on the base while the transistor that is turned off, will have zero volts on the base. As the anodes of the two signal diode are brought lower, the transistor that is turned on, will begin to turn off and the other transistor will begin to turn on via its 100u and 47k. As it begins to turn on, the transistor that was originally turned on will get less "turn-on" from its 100u and 47k and thus the two switch over very quickly. The collector of the third transistor can be taken to a buffer transistor to operate a relay or other device.

The next VOX circuit activates a relay when audio is detected by the microphone. The relay is kept activated for 5 seconds after a silent period, by the 22u, to keep the relay fully activated during normal speech. The circuit takes 0.5mA when "sitting around."

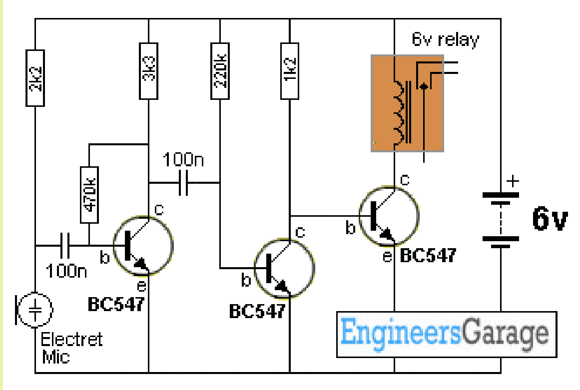


SENSITIVE VOX CIRCUIT

(Good design - circuit takes 0.5mA. Circuit keeps electro charged)

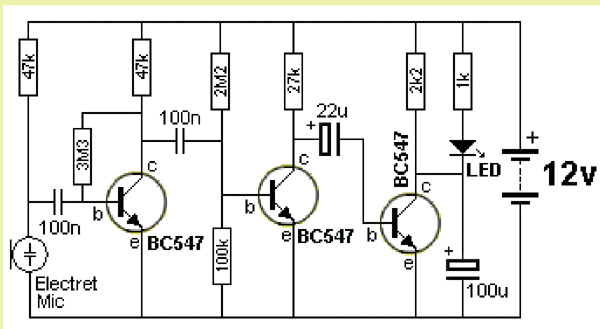
The circuit above is the best design as it uses the least number of components and drives a relay.

The next circuit comes from Engineers Garage website. It uses fewer components but takes more current (about 6mA) in the quiescent mode and does not have any delay to hold the relay ON:



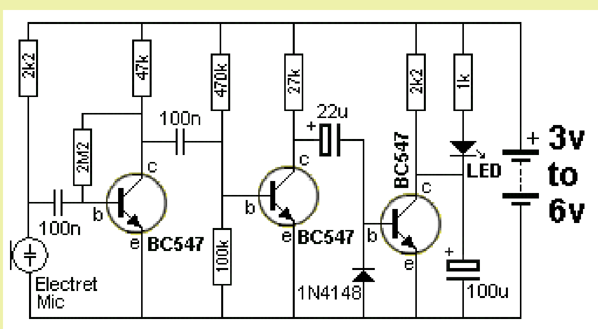
A 6v VOX CIRCUIT - no delay
(Not a good design - circuit takes 6mA)

The following two circuits detect audio and keep the LED illuminated for about 5 seconds. The delay is proved by the 100u capacitor on the output. The output is normally HIGH and goes LOW when audio is detected.
The LED shows the condition of the output. It is removed when you add the circuit to a project.
This circuit is the 12v version. Quiescent current (idle current) is 0.5mA.



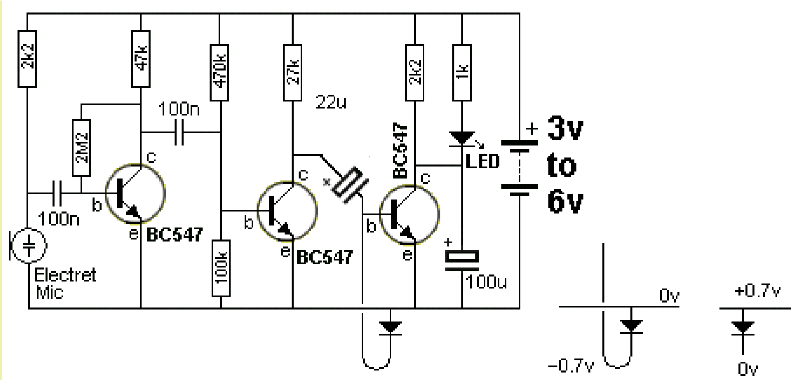
12v VOX CIRCUIT
(Good design - circuit takes 0.5mA. Circuit keeps 100u discharged)

The following circuit is similar to the above. It is the 3v to 6v version. These two circuits detect the slightest whisper. Quiescent current (idle current) is 0.25mA.



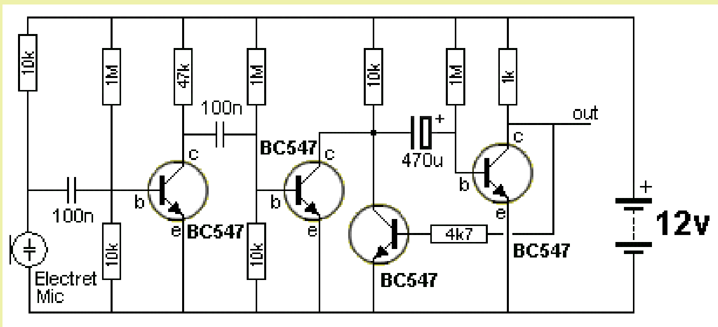
3v to 6v VOX CIRCUIT
(Good design - circuit takes 0.25mA. Circuit keeps 100u discharged)

The addition of the diode in the 3v circuit is needed to discharge the 22u so that it produces its "full effect" to saturate the output transistor when required. It is not needed in the 12v circuit as the base-emitter junction of the output transistor "zeners" at about 5v and this helps to partially discharge the 22u. But when only 3v supply is present, the 22u has a maximum of only a few volt on it and none of its voltage will be removed. The output transistor is turned on when the middle transistor turns off. The 27k pulls the 22u high and if it is discharged, it pulls the base of the third transistor "up" and turns on the LED. During this time it gets charged slightly and this charging current flows via the base of the third transistor to turn it on.
When the second transistor turns on, the 22u effectively "drops down" and the voltage across it (say 2v) will take the negative lead of the electro BELOW the 0v rail of the circuit. As soon as the negative lead is 0.7v below the 0v rail, the diode comes onto action.
As far as the diode is concerned, it sees a voltage of +0.7v on the anode lead with respect to the cathode lead and current will flow through it to discharge the electro. If the diode is removed, it would take a voltage of about -5v on the electro before it is discharged via the base-emitter junction of the transistor.



The 22u is discharged via the diode

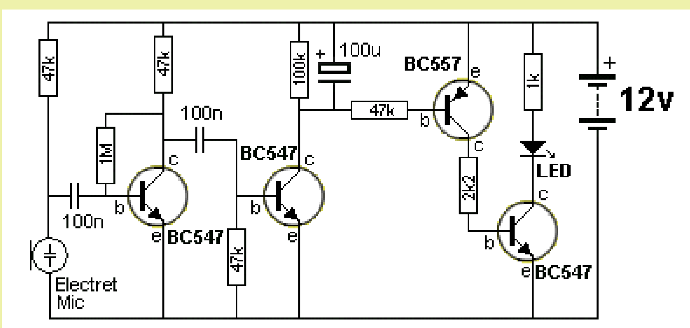
The next circuit is designed by electroschematic.com. It is not a good design.
The circuit takes 14mA when sitting around and the 470u electro only needs to charge by about 0.5v before the circuit changes state. This uses only a fraction of the possible time delay for a 470u capacitor if the circuit is designed to charge it to a higher voltage before changing state.



12v VOX CIRCUIT

(Not a good design - circuit takes 12mA)

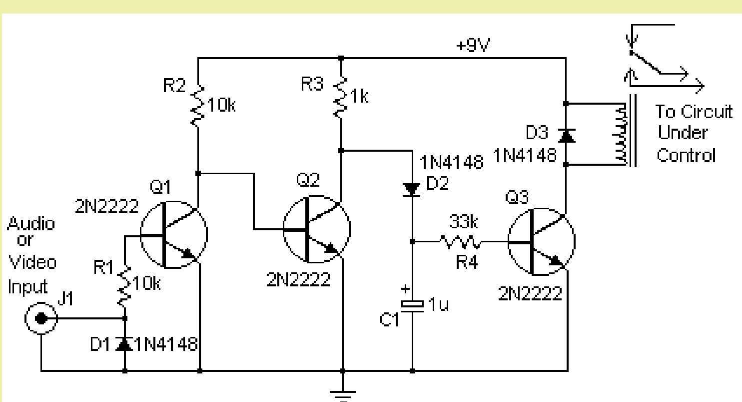
Here is the circuit re-designed to take less quiescent current (0.5mA) and provide a longer delay with 100u electrolytic (20 seconds).



12v VOX CIRCUIT

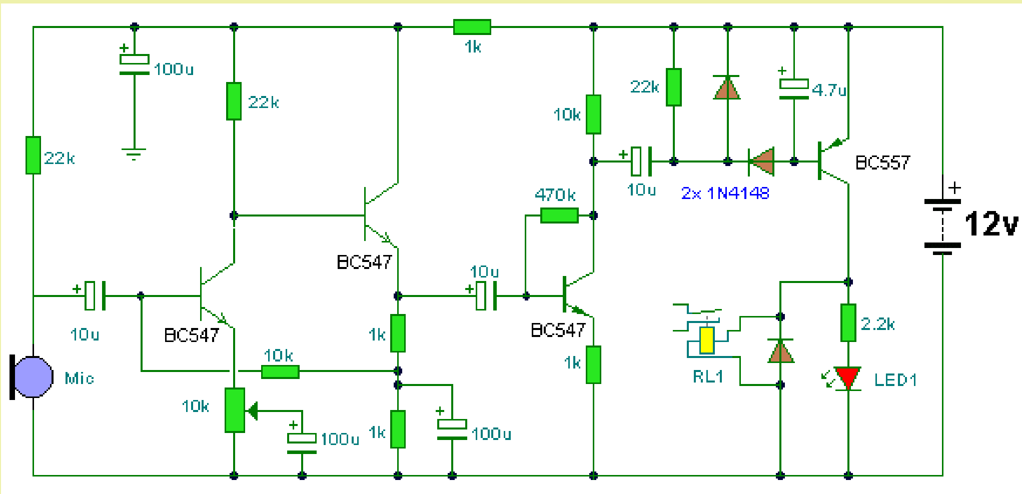
(Good design - circuit takes 0.5mA.)

The next circuit can be Voice Operated or activated by a Video signal.



The circuit activates a relay when an audio or composite video signal is delivered to the input. This allows you to use the tuner built into your VCR to turn on and off older TVs that are not equipped with a remote. It can also be used to activate surround-sound equipment, turn off room lights, turn on video game consoles, etc.
When power is applied, the first transistor is not turned on and the second transistor gets turned on via the 10k resistor. This prevents the third transistor turning ON and the relay is not energised.
When an audio or video signal is delivered to the input, the first transistor turns ON and this turns OFF the second transistor. The third transistor gets turned ON via the 1k and diode after the 1u gets charged a small amount.
When the input signal ceases, the first transistor turns OFF and this turns ON the second transistor. The third transistor no longer gets base current via the diode but the 1u holds a small amount of energy and this is delivered to the base to keep the relay active for a short period of time. After this the transistor turns OFF and the relay is de-energised.

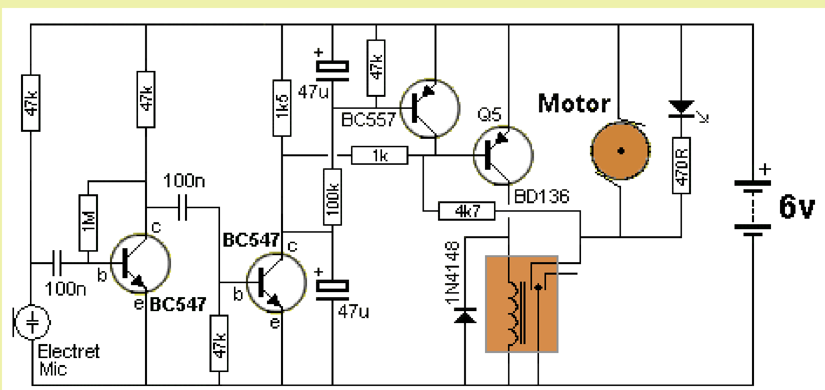
The next circuit is a little over-complex and could be improved.
Here are some suggestions:
1. The 10u from the microphone can be as low as 100n without any decrease in performance.
2. The 10k to the base of the first transistor should be a higher value to increase the input impedance of the first stage.
3. The 100u on the emitter of the first transistor can be replaced with a link.
4. The third transistor has a gain of 10. This can be increased by reducing the 1k.
5. The 22k and the two diodes can be removed and the circuit re-designed as shown above.
6. The 4u7 on the base of the 4th transistor is only charging to 0.7v. The delay section needs to be on the third transistor as shown above in the **12v VOX Circuit** and the fourth transistor should be a driver transistor.



This circuit can be improved

VOX TOGGLE

This clever circuit turns on a motor with a short whistle and turns the motor off with a long whistle. It's a toggle arrangement.



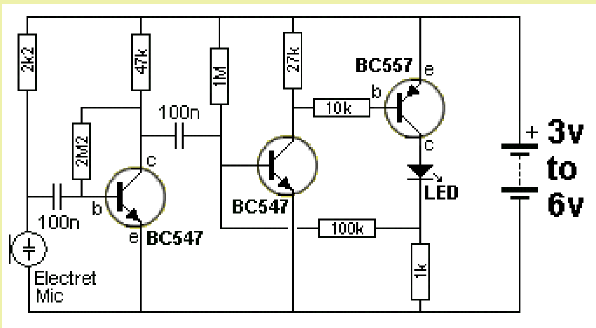
VOX TOGGLE CIRCUIT
Short tone = ON Long tone = OFF

The circuit allows a whistle to turn an appliance ON and OFF by sending a short whistle to turn a circuit ON and a long whistle to turn a circuit OFF.
This is handy when you cannot see the result of your operation. A simple toggle operation is not suitable as you do not know the state of the output at the start of the operation.
By sending a long whistle, you definitely know the output will be OFF and you can then control the output remotely.

A short whistle is less than 0.25 sec and a long whistle can be any length longer than 1 second.
These times can be adjusted by changing the value of the components.
When a short whistle is received, the lower 47u discharges and pulls the base of the BD136 towards the 0v rail and turns the transistor ON. This activates the relay and the contacts take the 4k7 to the 0v rail to keep the transistor ON.
During this time the top 47u charges via the 100k but not enough voltage appears across it to turn on the BC557 transistor.
If the whistle appears for a long period of time, the top 47u charges and turns on the BC557 and the voltage between the emitter/collector terminals is less than 0.3v. This voltage is too low for the BD136 to remain on and it turns off.
When the whistle stops, the BC557 remains on for 1 second and then turns off.
The circuit is then ready to be activated again.

VOICE OPERATED LATCH

The following circuit latches a LED **ON** when sound is detected. It can be used to confirm a certain level of sound has been reached or exceeded during an event.



Sound makes LED stay ON

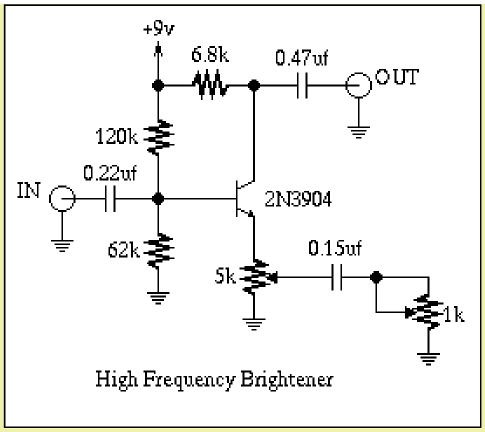
The electret mic and first transistor are active when the circuit is "waiting for a sound" and the 3rd and fourth transistors are biased OFF due to the 1M and 100k voltage-dividing resistors putting a voltage of between 0.27v and 0.54v on the base of the second transistor. This voltage is not high enough to turn the transistor ON. But the voltage helps to turn the circuit ON when audio is detected and makes it very sensitive.
You can see a poorly designed VOX latch circuit (Called Puff to OFF LED) in our Spot The Mistake eBook.
These poorly-designed circuits show you how NOT to design a circuit and are just as informative as a good design.

ANALOGUE and DIGITAL mode

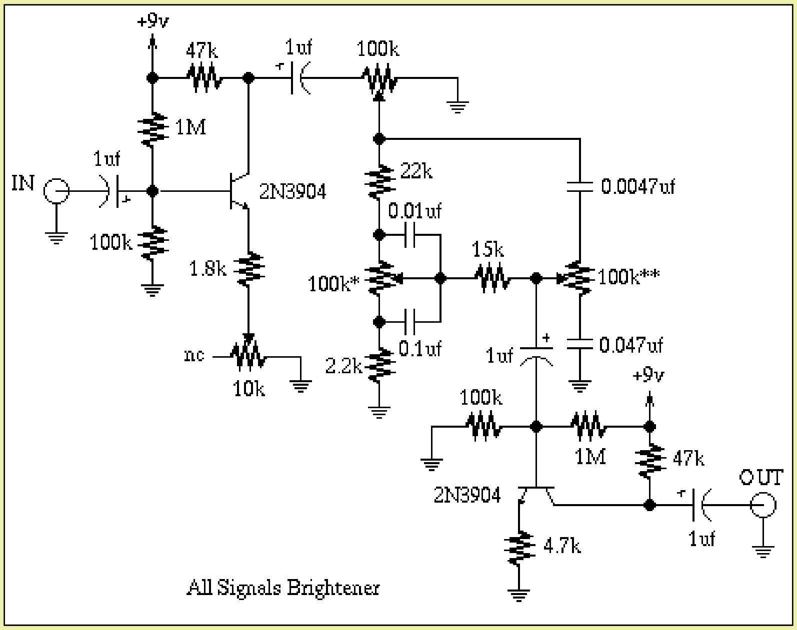
Now that we have covered more than 100 different circuits, you can see each transistor in a circuit is operating in either analogue or digital mode.
Sometimes it is easy to see the mode of operation.
If a transistor is not taking any current, then gets turned on (hard or fairly hard) it is operating in DIGITAL MODE.
If it is turned on with the collector at or about mid-rail voltage, it is in ANALOGUE MODE.
Understanding these two modes is very important because a transistor in digital mode wastes the least energy. However it cannot amplify a signal that has an amplitude less than 0.6v. It can only amplify a signal that is greater than about 0.7v.
That's why some circuits need both types of stages.
A well-designed circuit takes the least current in quiescent mode.
We have also shown how one stage transfers energy to the next stage via a capacitor. But a capacitor creates losses.
Direct-coupling transfers more energy and has no loss.
When designing a circuit it is best to refer to the circuits covered in this eBook, to prevent designing something that may not work correctly.
We have exposed many poorly-designed circuits in our "**Spot The Mistake**" eBook, as explained above.

CLIPPING AND DISTORTION

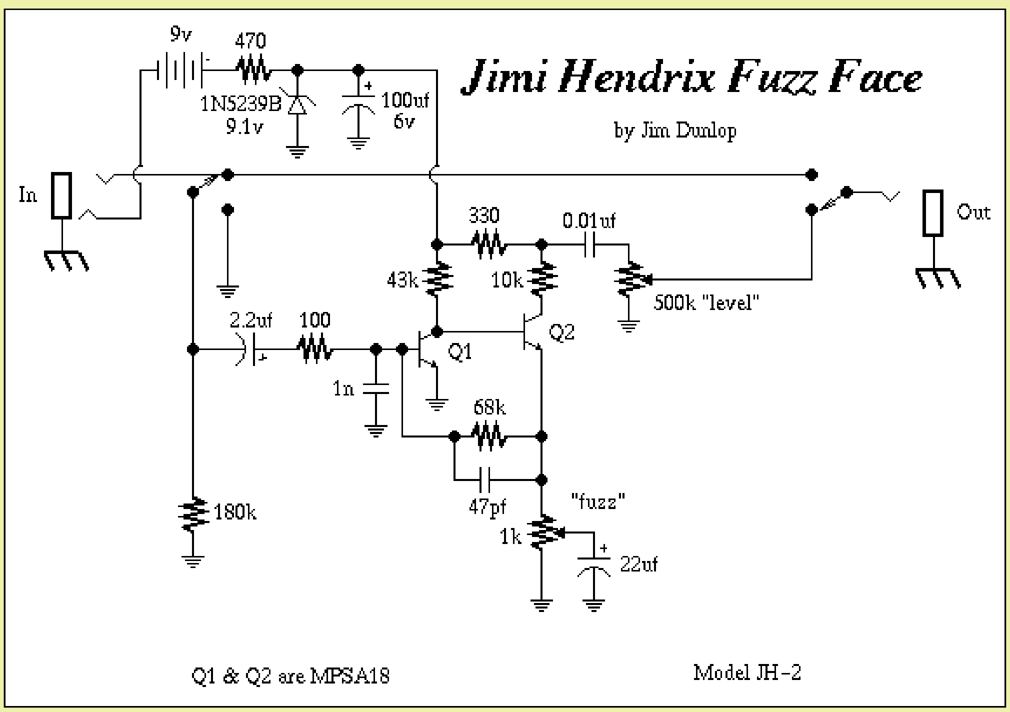
Most Analogue circuits require a stage to reproduce a signal as accurately as possible. After all, we don't want an amplifier to be distorted.
However some analogue circuits are designed to distort a signal. Therese can be classified as "EFFECTS" circuits and the most common is a guitar effect called FUZZ. A Fuzz circuit clips a signal so the full amplitude is not delivered to the output.
There are many ways to distort a signal (or process a signal) so a desired effect can be achieved and there are dozens of names for these circuits.
There is no "electronics rationale" behind the design of these circuits and many of them come from experimenting and placing components in unusual places to create positive or negative feedback or overdrive a stage or even under-drive the active component (usually a transistor or op-amp).
There are hundreds of circuits to create these "EFFECTS" and here are some:

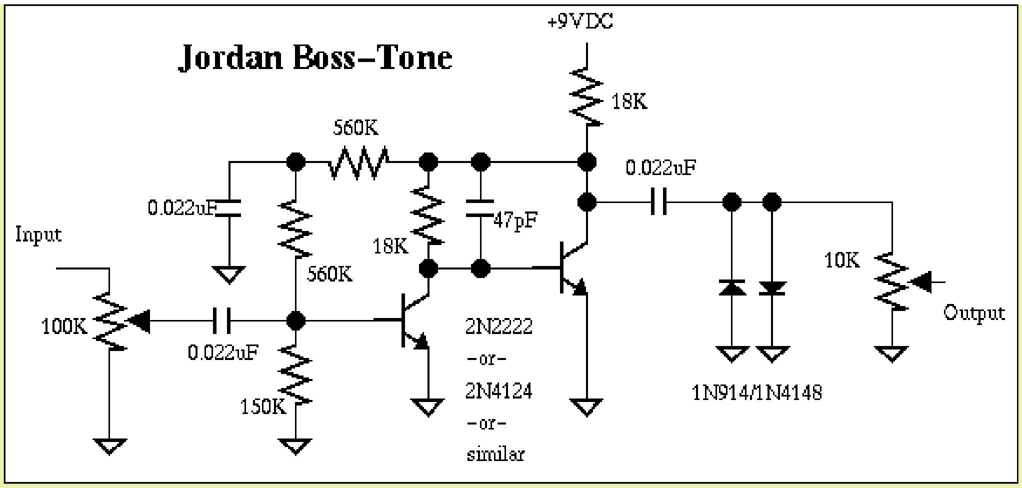


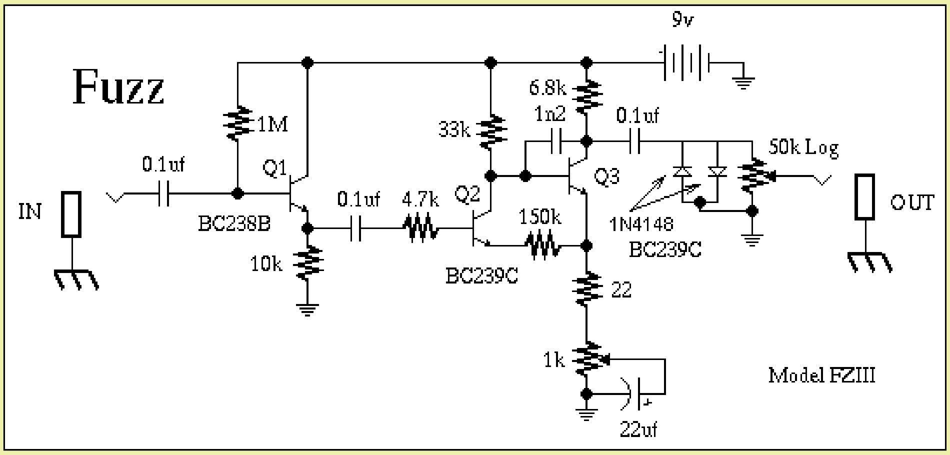
High Frequency Brightener

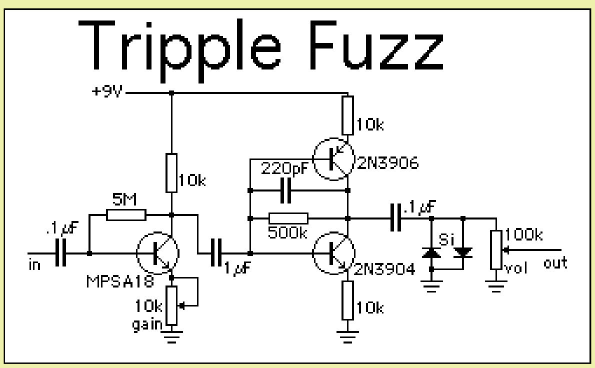


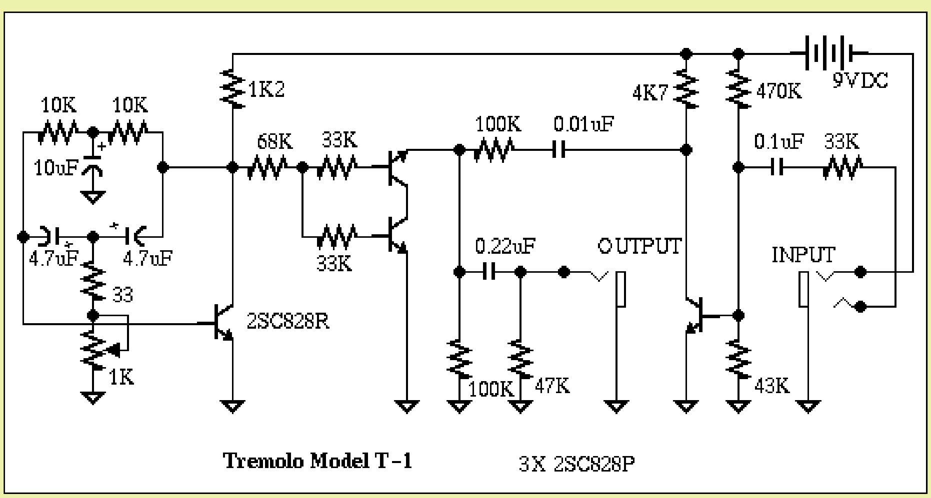
All Signals Brightener

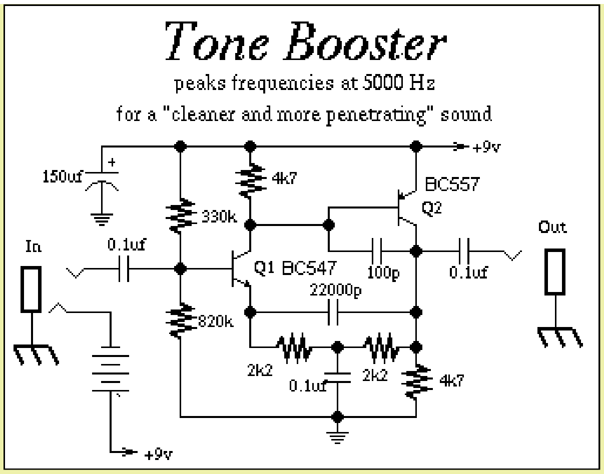


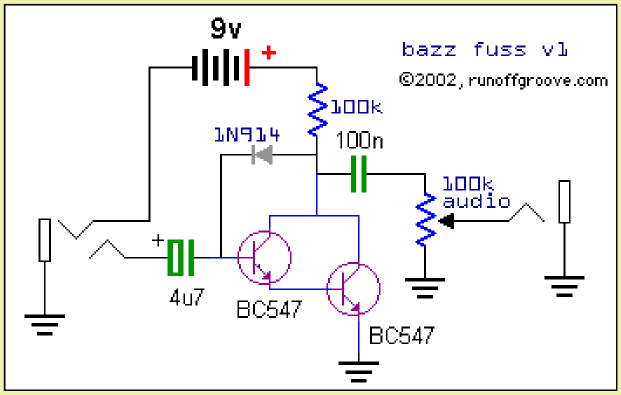

Jordan Boss-Tone
+9VDC
18K
560K
0.022uF
0.022uF
47pF
18K
Input
560K
10K
100K
0.022uF
2N2222
-or-
2N4124
-or-
similar
Output
150K
1N914/1N4148

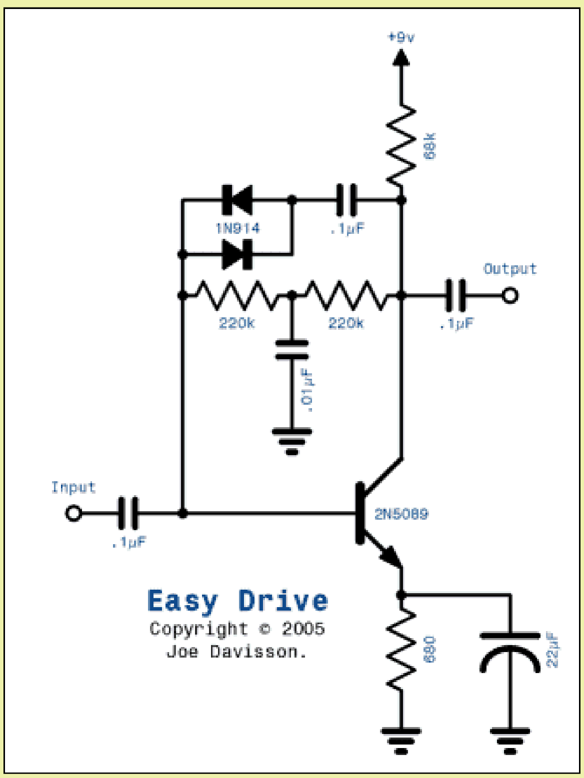

Fuzz
9v
6.8k
1n2
0.1uf
50k Log
1M
33k
0.1uf
Q1
Q3
0.1uf
4.7k
Q2
IN
OUT
BC238B
150k
1N4148
BC239C
10k
BC239C
22
1k
Model FZIII
22uf


Tripple Fuzz
+9V
10k
2N3906
220pF
10k
5M
.1µF
500k
.1µF
Si
100k
in
1µF
2N3904
vol
out
MPSA18
10k
gain
10k

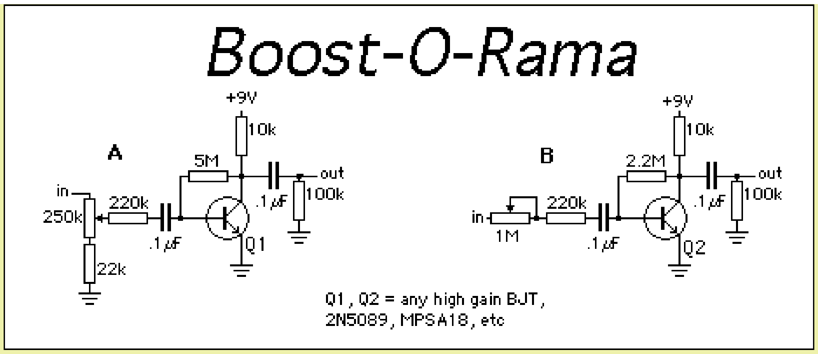

1K2
4K7
470K
9VDC
10K
10K
100K
0.01uF
68K
33K
0.1uF
33K
10uF
4.7uF
4.7uF
33K
0.22uF
OUTPUT
INPUT
33
2SC828R
1K
100K
47K
43K
Tremolo Model T-1
3X 2SC828P

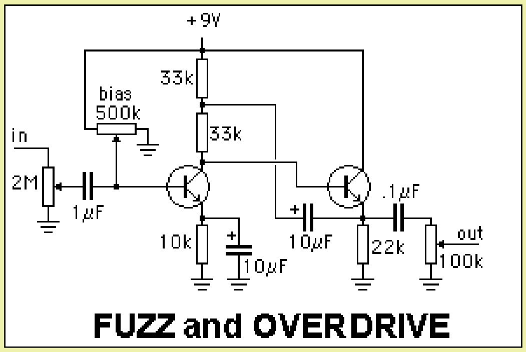


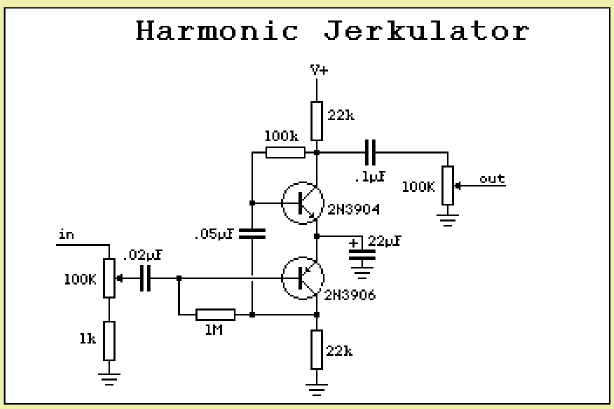


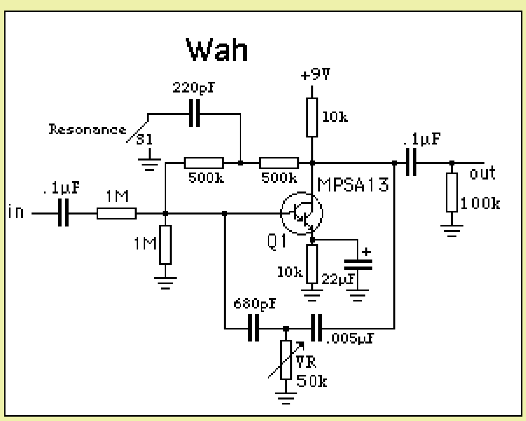


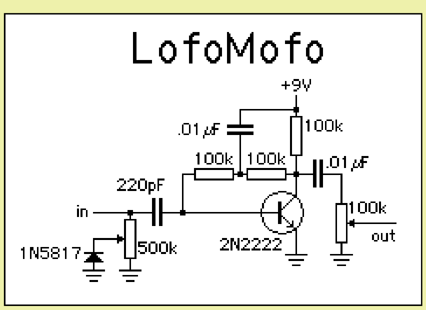
An OVERDRIVE Circuit

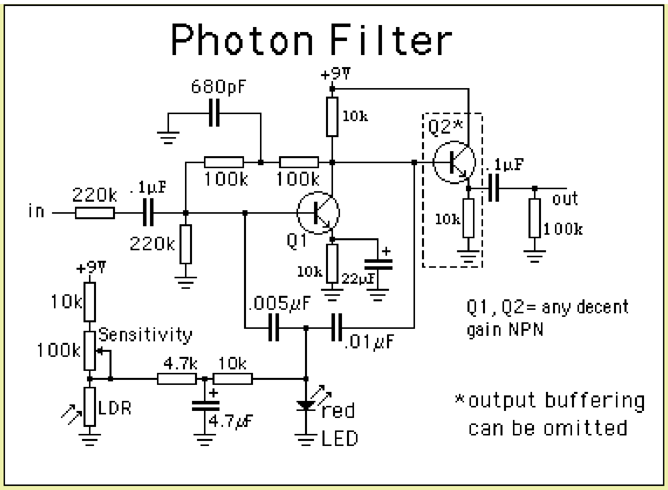

Boost-O-Rama
A
B
+9V
10k
5M
2.2M
out
100k
.1µF
in
250k
220k
22k
1M
Q1
Q2
Q1, Q2 = any high gain BJT,
2N5089, MPSA18, etc

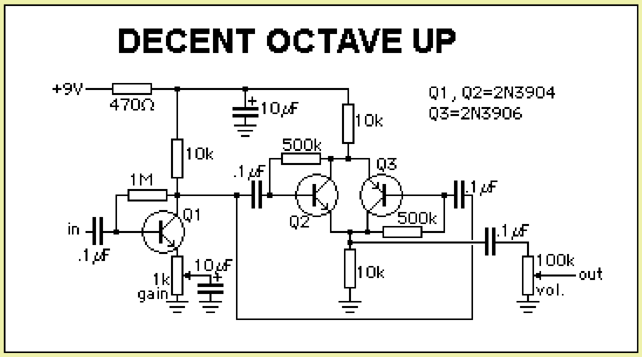

+9V
33k
bias
500k
33k
in
2M
1µF
10k
10µF
10µF
22k
.1µF
out
100k
FUZZ and OVERDRIVE

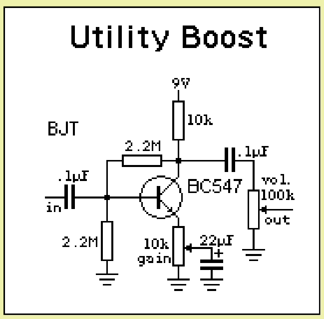

Harmonic Jerkulator
V+
22k
100k
.1µF
100K
out
2N3904
.05µF
22µF
in
.02µF
100K
2N3906
1M
1k
22k

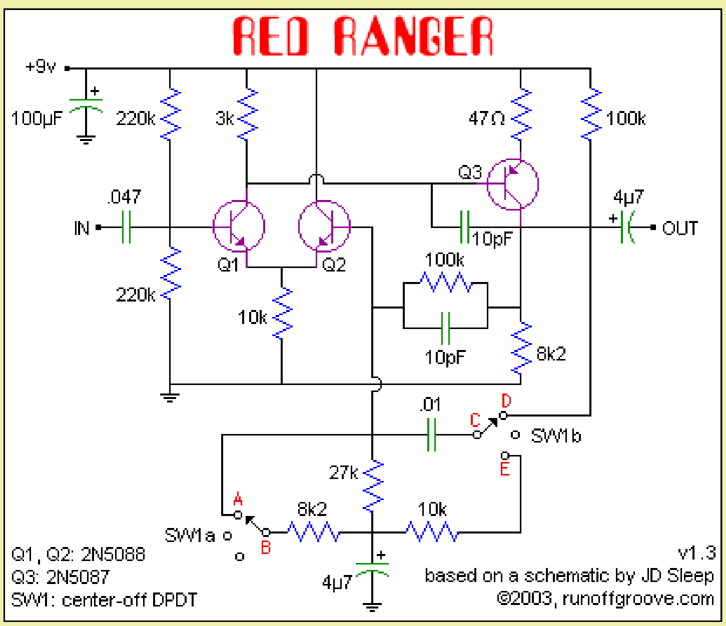

Wah
220pF
+9V
10k
Resonance
S1
500k
500k
.1µF
out
100k
MPSA13
.1µF
1M
in
1M
Q1
10k
22µF
680pF
.005µF
VR
50k

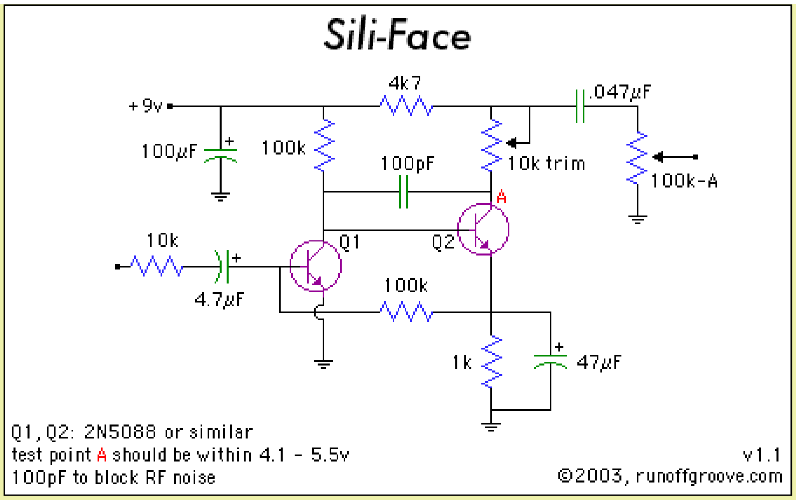

LofoMofo
+9V
.01µF
100k
100k
100k
.01µF
220pF
in
100k
out
1N5817
500k
2N2222

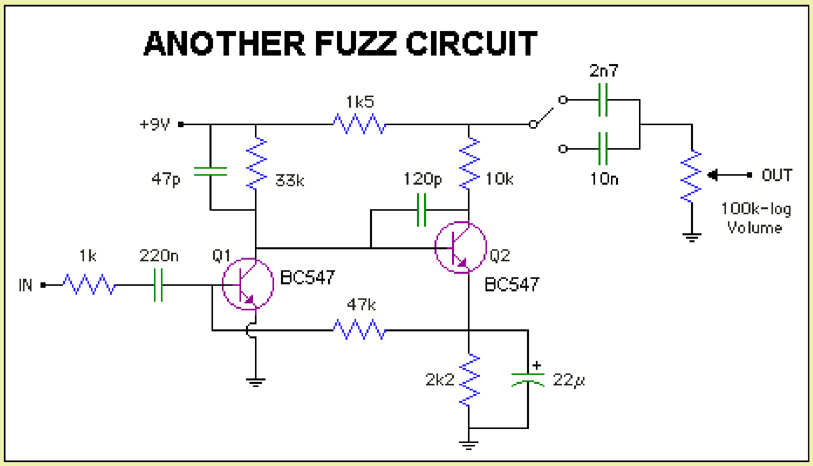

Photon Filter
+9V
680pF
10k
Q2*
.1µF
100k
100k
220k
.1µF
in
out
10k
100k
220k
Q1
+9V
10k
22µF
10k
.005µF
Q1, Q2= any decent gain NPN
Sensitivity
100k
.01µF
4.7k
10k
LDR
4.7µF
red
LED
*output buffering can be omitted

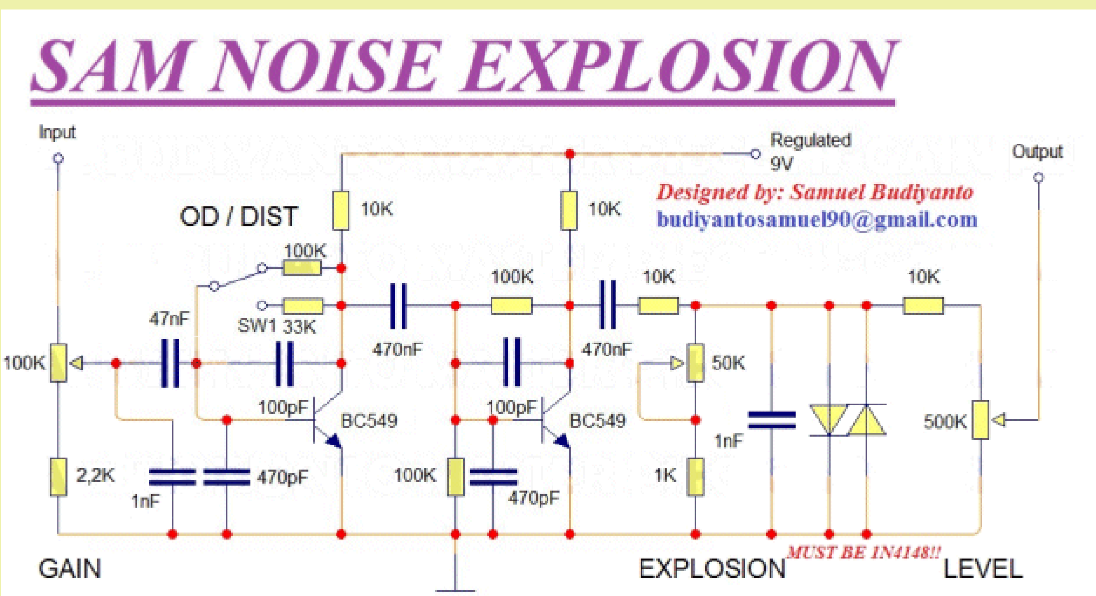

DECENT OCTAVE UP
+9V
470Ω
10µF
10k
Q1, Q2=2N3904
Q3=2N3906
10k
500k
.1µF
Q3
1M
1µF
Q1
Q2
500k
in
.1µF
.1µF
10µF
1k
gain
10k
100k
out
vol.


Utility Boost
9V
10k
BJT
2.2M
.1µF
.1µF
BC547
vol.
100k
in
out
2.2M
10k
gain
22µF

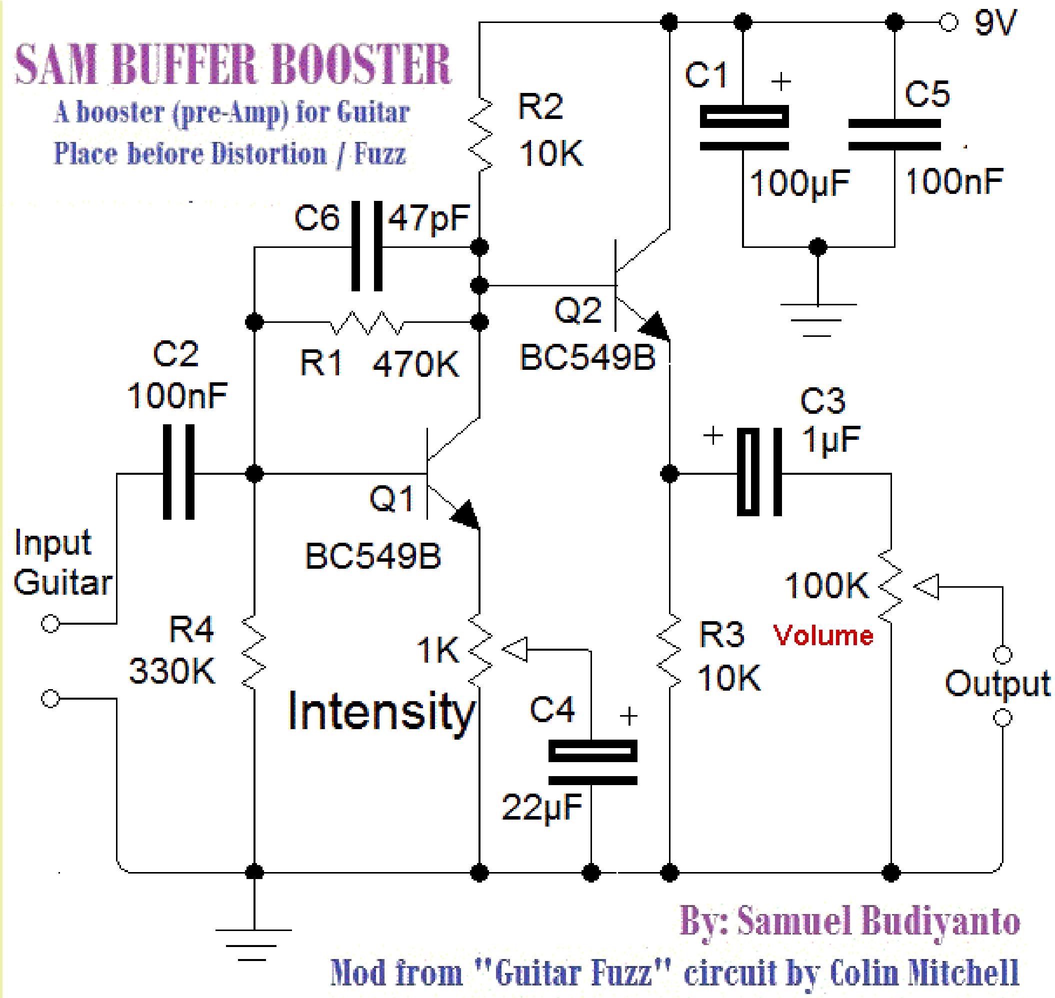

RED RANGER
+9v
100µF
220k
3k
47Ω
100k
Q3
.047
4µ7
IN
10pF
OUT
Q1
Q2
100k
220k
10k
10pF
8k2
.01
C
D
SW1b
E
27k
A
8k2
10k
SW1a
B
Q1, Q2: 2N5088
Q3: 2N5087
SW1: center-off DPDT
4µ7
v1.3
based on a schematic by JD Sleep
©2003, runoffgroove.com







This produces a ROCK PEDAL with very good performance.

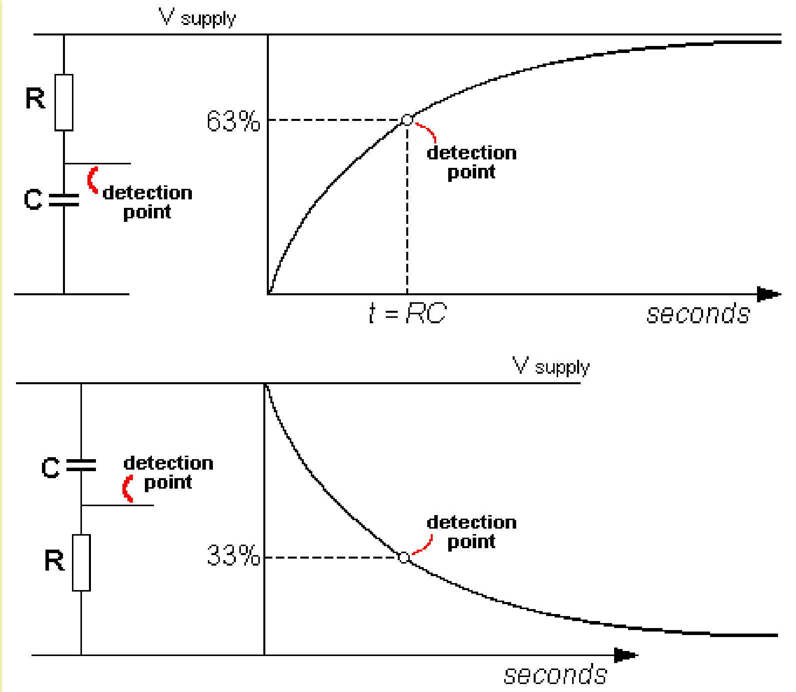


This circuit takes the small signal from the magnetic pick-up and amplifies it 10 to100 times and removes some of the noise via the 47p capacitor.
Insert this circuit before Overdrive / Distortion / Metal / Chorus / Delay and the result is like a very expensive high quality guitar.

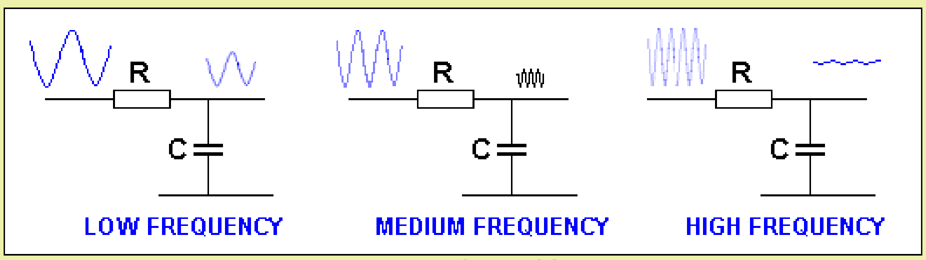
The following website has SOUND CLIPS for lots of different effects:
http://www.home-wrecker.com/salvo.html#bazzfuss

Integration and Differentiation

We are going to show how two components, (a resistor and capacitor - in series) produces different results according to the frequency of a voltage (signal, waveform) delivered to them. We also have different names for the two "series components," depending on the actual circuit using the components. We have already covered the TIME DELAY circuit and shown it consists of a resistor and capacitor in series. The join of the two components is detected by a transistor or Integrated Circuit and when a particular value of voltage is reached, the circuit produces results as shown below. When the circuit is first turned ON, the voltage gradually RISES when the capacitor is below the resistor or gradually FALLS when the capacitor is above the resistor.



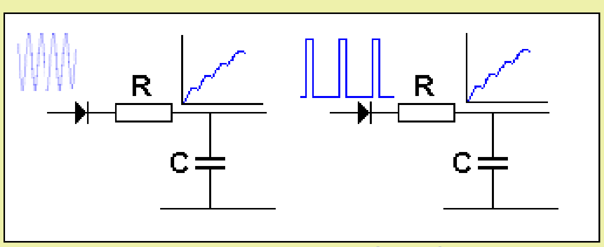
But if we connect the same two components to a rising and falling voltage, a completely different result is produced.
If the input is a sine-wave, the following results are produced when a low-frequency, medium-frequency or high-frequency is supplied to the input:



The circuit is a LOW PASS FILTER

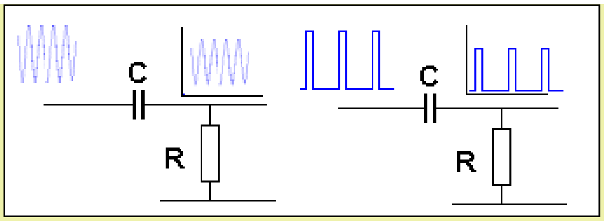
You can see the output waveform almost disappears when a high-frequency is delivered to the input. (It disappears in amplitude, but a voltage appears across the capacitor that is approximately the average of the high and low values.)
This means the circuit is capable of removing high-frequency portions of a waveform. If the waveform consists of a mixture of low-frequencies and high-frequencies, only the low-frequencies will appear on the output.
In other words the circuit is a FILTER and it only passes the LOW FREQUENCIES.
In other words it is a **LOW PASS FILTER**.

We now look at the circuit above when ANY frequency is delivered to the input. This time we will eliminate the effect of the waveform when it is falling, by adding a diode to the input.
You will notice a voltage builds-up on the capacitor. This is because the input voltage is charging the capacitor a little-bit more on each cycle. The circuit becomes an INTEGRATOR. It does not matter if the waveform is a sinewave or square-wave - the capacitor gradually becomes charged.



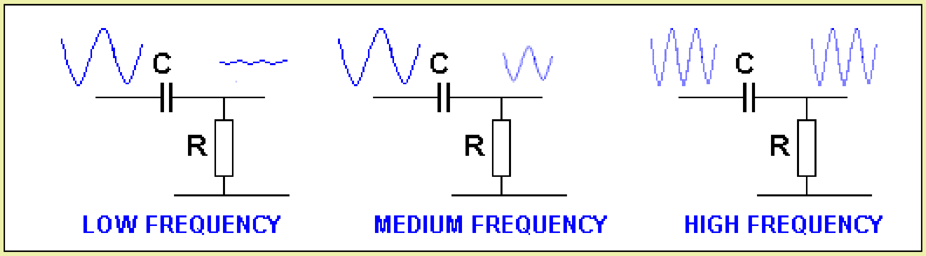
The circuit is an INTEGRATOR
- it gradually charges the capacitor

If we deliver the waveform to the circuit with the capacitor above the resistor, the output is not integrated:



The circuit is NOT an INTEGRATOR

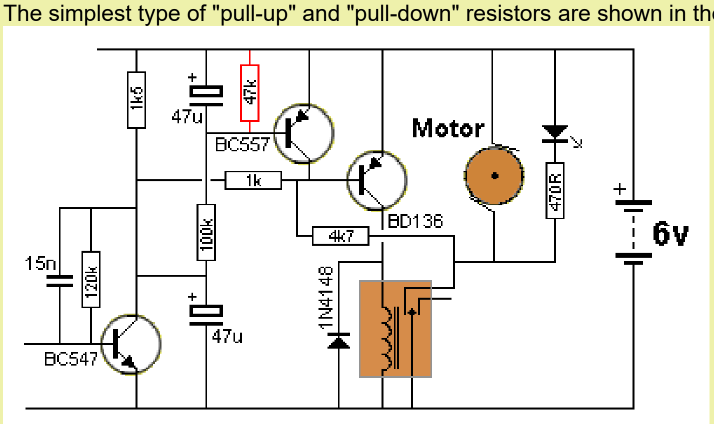
So, what is the purpose of the circuit with the capacitor above the resistor?
The following results are produced when a low-frequency, medium-frequency or high-frequency is supplied to the input:



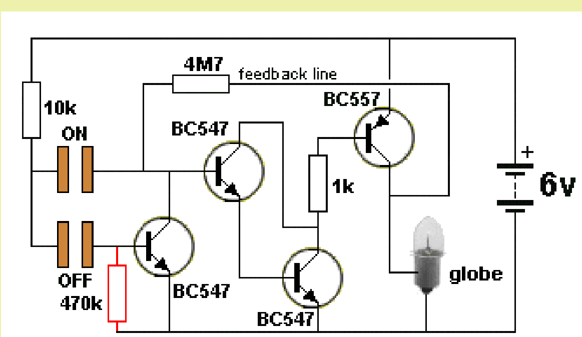
We see the low-frequency waveform is attenuated (reduced) while the high-frequency waveform passes through the circuit.
This produces the name "HIGH PASS FILTER."
It is also given the name "DIFFERENTIATOR."
This means only the high-frequency portions of the input waveform will be delivered to the output.
If we have a waveform consisting of low-frequency and high-frequency components, only the high frequency parts will be delivered to the output.

PULL-UP and PULL-DOWN Resistors

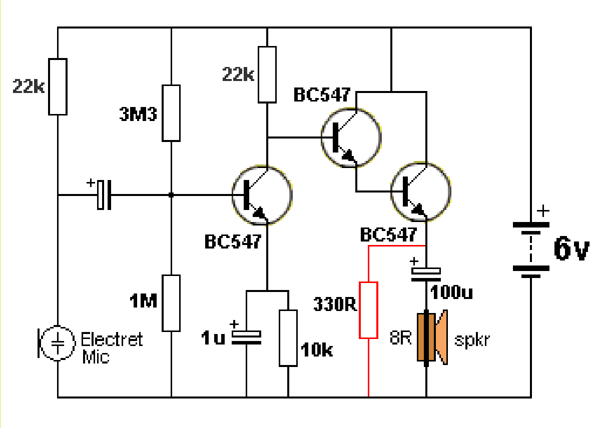
The simplest type of "pull-up" and "pull-down" resistors are shown in the following diagrams:



The 47k is a "Pull-Up" resistor. The designer of the circuit wants the base of the transistor to be at a known voltage when the circuit is sitting around, waiting for a signal. The 47k forms a voltage-divider with the 100k and BC547 and it makes sure the BC557 is turned off when the circuit is waiting for a signal. It is pulling the base "UP" so the BC557 is not turned on.



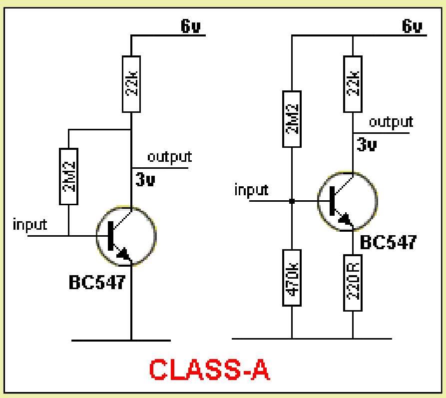
The 470k is a "Pull-Down" resistor. It prevents the BC547 generating a static voltage on the base and turning the circuit OFF.



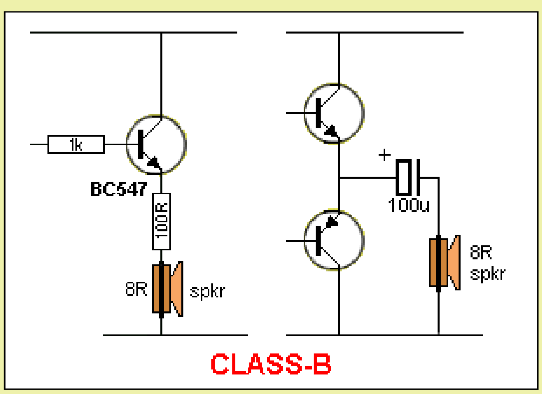
The 330R can be classified as a "pull-down" resistor. It is also part of the load for the output stage.

CLASS-A CLASS-B CLASS-C

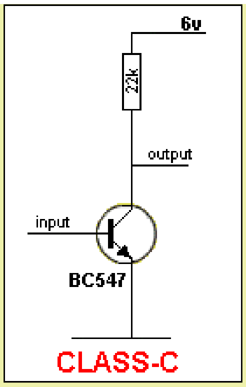
Each stage in a circuit can be given a name according to its efficiency. Normally the output stage is the only stage that is classified as "A" "B" or "C" because this is where most of the efficiency or losses occur. However the same criteria applies to the other stages in a circuit and this can give you some indication of the performance of each stage.
The most inefficient stage is classified as **CLASS-A**. It has an efficiency of 25% to 50%.
However it is the best stage for amplifying audio signals as it produces perfect reproduction and amplification. High Fidelity amplifiers are class-A throughout. The stage is biased so the collector is at half-rail voltage. This allows the stage to amplify both the positive and negative portions of the signal.



CLASS-B is basically an **EMITTER-FOLLOWER** stage. It is also called **PUSH-PULL** when two emitter-follower transistors are connected together. Push-pull has an efficiency of 78% max. The stage only amplifies the positive portions of the signal. When two transistors are connected, one amplifies the positive portion of the signal and the other amplifies the negative portion of the signal.

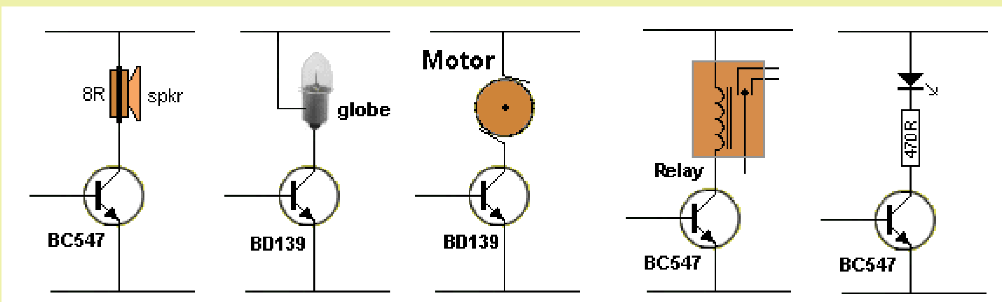


CLASS-C does not have base-bias. It consumes no current when "sitting around" and efficiencies up to 90% are possible.
The energy to turn the transistor ON (and drive the base) must from the input signal. The stage only amplifies the positive portions of the signal and has high distortion, but it can be used in certain applications with very good results.



THE DRIVER STAGE

Any transistor that drives a **LOAD** is said to be a **DRIVER** in a **DRIVER STAGE or OUTPUT STAGE**. A **LOAD** is generally a relay, motor, globe, LED or other device that requires a **CURRENT**.
The following diagrams show a DRIVER (or OUTPUT) TRANSISTOR driving a LOAD:



The transistor driving a LOAD

In most circuits, achieving a **CURRENT** to drive a load is the most difficult thing to do.
The **voltage** for the LOAD is easy to get. It is the voltage of the supply. The supply (RAIL VOLTAGE) can be set to match the requirement of the LOAD. If you have a 6v motor, use a 6v supply. If you have a 12v relay, use a 12v supply.
Achieving (getting, supplying) the **current** for the LOAD is the requirement of the transistor - the DRIVER transistor or commonly called the OUTPUT transistor.
The first thing you have to know is the amount of current for the LOAD. This is generally expressed in milliamp (mA) or Amp (A). 1,000mA = 1Amp.
In some cases this is easy. It is on the specification-sheet - such as a LED requires 25mA and a relay requires 90mA. But if a relay states "12volt 100R", you will have to work out its current. It's a simple Ohm's Law equation:

$$I_{(amps)} = \frac{V_{(volts)}}{R_{(ohms)}}$$

To save mathematics, we have provided the current requirement for a number of relays:
5v relay 100 ohms 50mA
5v relay 240 ohms 20mA
9v relay 100 ohms 90mA
9v relay 240 ohms 40mA
12v relay 100 ohms 120mA
12v relay 240 ohms 50mA

The current for some loads is unknown. For example, a 6v or 12v motor will take more current when starting or when heavily loaded. The starting current can be 6 times the running current and this is what the driver transistor must be able to provide. In fact the running current is not known until you try the motor. It can be 50mA, 100mA, 250mA or even 1amp. The starting current can be 6 times the running current.
This is what you have to do:
Connect the motor to the supply (without a transistor driver) and add an ammeter in series with one lead. Turn the motor ON and hold the shaft. Quickly read the current. Release the shaft and read the running current.
Suppose a motor requires 600mA to start and 100mA to run. In other words, the motor will take 100mA when lightly loaded and 600mA when heavily loaded.
The driver transistor will be required to supply 600mA to start the motor (and when it is under load) and when it is running under almost no-load, the current will drop to 100mA.

For a transistor to supply 100mA to 600mA to the motor, we must deliver current to the base. The transistor simply amplifies the current we supply to the base. The amplification factor is called the CURRENT

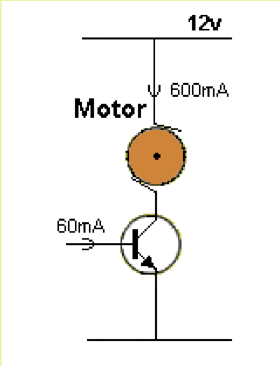
AMPLIFICATION or CURRENT GAIN and is normally 100, but this only applies when the transistor is lightly loaded.

CURRENT GAIN
If a transistor has a CURRENT AMPLIFICATION of 100, 1mA into the base will allow 100mA to flow in the collector-emitter leads (collector-emitter circuit).
But if a transistor is designed to handle 100mA, it will only deliver about 50mA when 1mA enters the base.
It may take 2mA base-current to get to 70mA, 5mA to get to 80mA and 10mA to get to 100mA.
To deliver 100mA, you will need a transistor capable of delivering about 300mA. That's because the larger transistor has a larger junction and is capable of handing the current.
For example, you will need a 300mA transistor to handle 100mA and a 1 or 2 amp transistor to handle 600mA.
This is a fact that is rarely explained.
When you choose the right transistor, it will remain fully saturated when 100mA is flowing and the voltage across the collector-emitter will be less than 0.5v. In other words, the transistor will remain FULLY SATURATED or FULLY CONDUCTING.
When the current exceeds the maximum rating, the transistor falls out of conduction. In other words the voltage across the collector-emitter terminals will increase above 0.5v and will gradually rise to 1v, 2v, 3v, or more as the current increases. When this happens, the wattage dissipated by the transistor increases and it gets very hot. The transistor may be able to deliver the higher current but the voltage across the load will be reduced as some of the voltage is lost across the transistor.

Let's take this in more detail:
When a transistor is fully saturated and passing 600mA, the collector-emitter voltage will be as low as 0.2v to 0.5v. The wattage dissipation will be: P=VI = 0.2 x.6 = 0.12watts or P=VI = 0.5 x.6 = 0.3watts
If the transistor comes out of conduction and produces 3v across the collector-emitter terminals, the wattage dissipation increases to: P=VI = 3 x.6 = 1.8watts This is an enormous increase in heat produced by the transistor. That's why you don't want a transistor to come out of conduction.

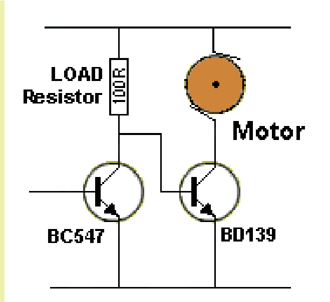
How do you know if a transistor has a gain of 10 or 100?
You don't. There is no way to know if a transistor has a gain of 10 or 100.
However if you follow our suggestions, you will be able to achieve the maximum gain:
Select a transistor capable of delivering 2, 3 or 5 times more current than is needed for the project you are designing. This will allow it to operate in its HIGH GAIN region because it will not be over-loaded.
Feel the temperature-rise of the transistor and use a heatsink to prevent it over-heating.

A transistor capable of supplying 1amp will be operating near its maximum when supplying 600mA and the base will need 60mA.
In the diagram below, the transistor is not controlling the current. It simply supplies the current demanded by the motor. If the motor requires 100mA, the required current will flow though the collector-emitter leads of the transistor. When the motor "asks for" 600mA, the transistor will deliver the current.
For this current to be available to the motor, the transistor must be turned ON and fully saturated.
The 60mA base current flows ALL THE TIME so that when 600mA is required by the motor, the transistor will deliver the current.
The following diagram shows the current required by the motor. Here's the important point. The circuit must be designed so that it can deliver 600mA **AT ANY TIME**. This means the transistor must receive a base current of 60mA **AT ALL TIMES**.
If you use a high-power transistor, it may have a gain of 50 or more when delivering 600mA and the base current will be lower, but we will take the case of the transistor having a gain of 10 when 600mA flows.



Base Current

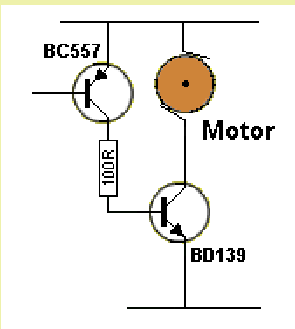
Base-current:
Base current comes from the previous stage in a circuit.
There are two ways to deliver this current:
1. via a load resistor
2. via a transistor.
We have already seen the inefficiency of delivering a current via a load resistor, as shown in the following circuit:



Base current supplied via a LOAD resistor

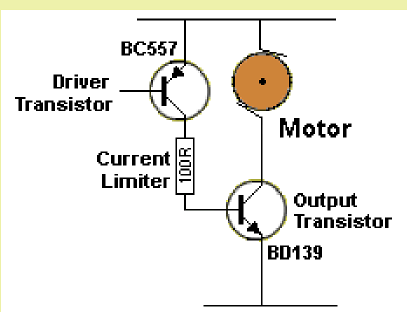
In the circuit above, current is always flowing through the 100R LOAD Resistor. The BC547 is merely diverting the current from the base of the output transistor to the 0v rail. We will not be describing this circuit arrangement.

It is much more efficient to deliver a current via the following type of circuit:

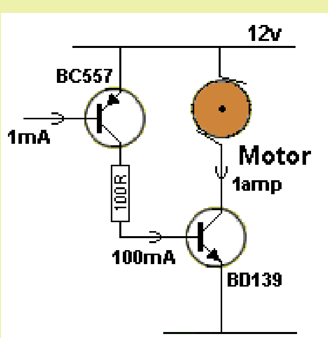


In the circuit above, current is only flowing through the 100R LOAD resistor when the PNP transistor is turned ON. The 100R CURRENT LIMITING resistor determines the base current for the output transistor.

We have now designed the best circuit for driving a LOAD:

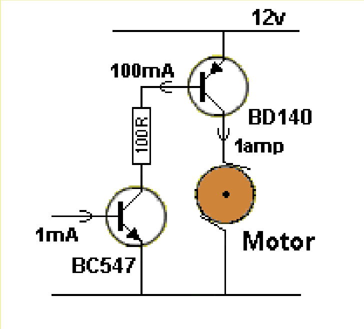


The approximate current in each leg of the circuit for 1Amp LOAD is as follows:



This means 1mA will control (deliver) 1amp (1,000mA) into a LOAD.

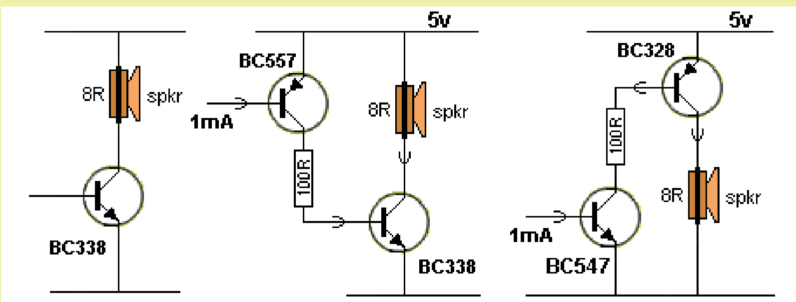
Here is the PNP-output circuit:



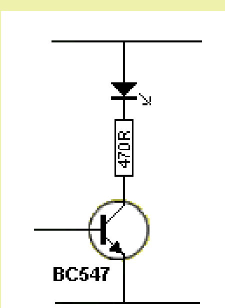
In Summary: When designing a circuit, we allow a current-gain of 100 when a transistor is lightly loaded and a gain of 10 when fully loaded. The driver transistor will have a gain of between 100 and may drop to 10 when full current flows. This means it will need 1mA base current for 100mA it delivers to the load when the gain is 100, but will need 10mA for 100mA, when it has a gain of 10.

This also applies to a globe (lamp) as the load. A globe requires 6 times more current to begin illumination because the filament is cold and its resistance is less than when it is hot.
To make sure the circuit will illuminate the lamp, the driver transistor must be able to deliver up to 6 times the operating current for a very short period of time.

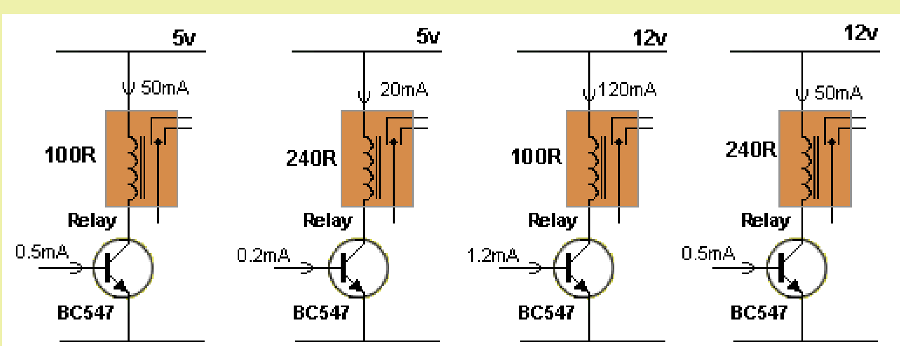
A transistor driving a speaker requires the same driver and output arrangement as driving a motor as it is a very low (impedance) resistance.



The situation is different with a LED. The current required for a LED is small and a small-signal transistor can supply the current and have a gain of 100. The current for a LED will be about 25mA and the base current will be less than 0.25mA



The current for a relay can also be provided by a small-signal transistor and the gain can be 100.



The base current must come from a previous stage

For low-current requirements, use a BC547 for the driver/output transistor. A BC547 will handle up to 100mA. Similar transistors include: 2N2222A, BC107, BC108, BC109, BC142,BC182L, BC337, and many others.

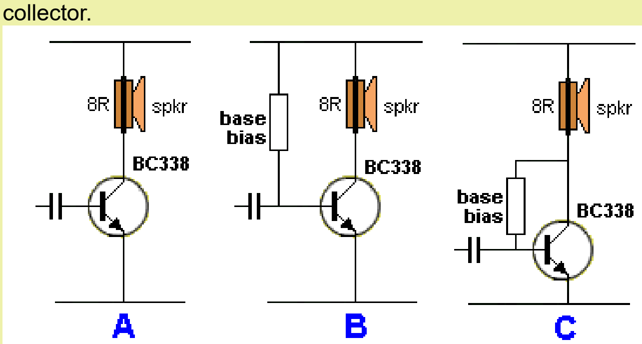
How to Design a DRIVER STAGE

For a HIGH CURRENT requirement, the NPN driver transistor needs to handle 1 amp or more.
For 1 amp use: BC142, BC337, BD131, BD139,
For more than 1 amp use: 2N3054, BD131, TIP31A and many others.

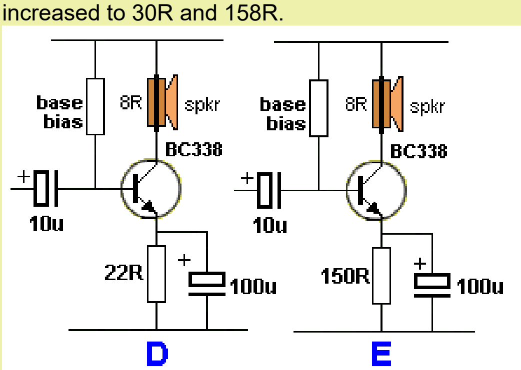
Use a heatsink.
To make sure the transistor stays IN CONDUCTION, measure the collector-emitter voltage when under FULL LOAD. The collector-emitter voltage must not be above 1v.

An 8R speaker puts a very heavy demand on any supply rail and this can cause glitches that may affect the operation of other sections of the circuit.

Fig A shows a speaker connected to a driver transistor. The circuit will work but the first 0.5v of the signal will not be reproduced as the transistor does not turn on until the base sees 0.6v. The circuit takes no current in quiescent mode as the transistor is not tuned on. The output will be distorted.
Fig B shows a base bias resistor connected to the positive rail. This resistor will have to be a low value (about 2k2 to 10k) to turn the transistor ON so that the collector will be at about half rail voltage. This will allow both the positive and negative excursions of the signal to be reproduced.
Fig C shows the transistor in self-bias mode. Figs B and C are very similar. The resistance of the base bias resistor will be slightly lower in fig C and selecting the right value will provide about half rail voltage on the collector.

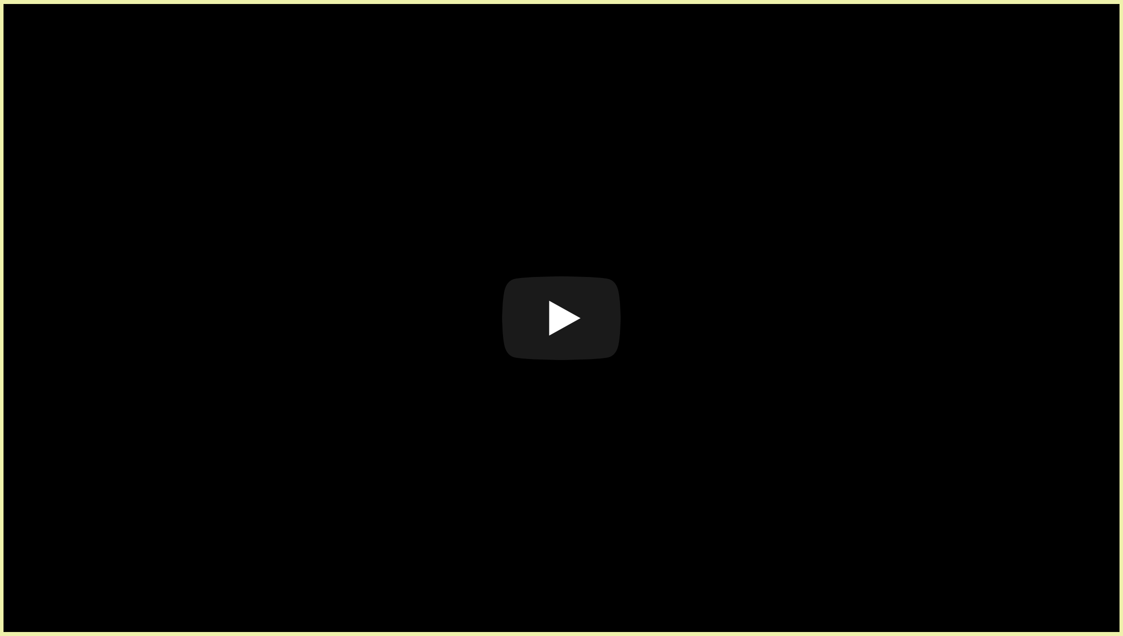


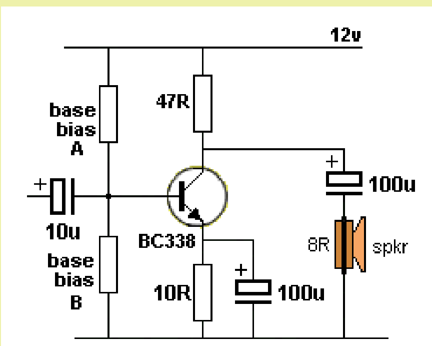
But the problem with all these circuits above is the high current taken by the stage.
As you can see, the load is only 8R and if the transistor is partly turned ON, the idle current will be very high. This can can be reduced by using the following circuits. The output volume will be reduced, but the current will be reduced considerably.
In the circuits above, the output impedance is 8R. In the circuits below, the output impedance has been increased to 30R and 158R.



The secret to the good performance of stages D and E is due to the 100u on the emitter. This electrolytic turns the stage into a common-emitter amplifier, just like circuits A, B and C, as far as the audio signal is concerned, but turns the LOAD into 30R or 158R as far as the DC current is concerned.
We get the best of both conditions at the same time.

DESIGNING AN OUTPUT STAGE

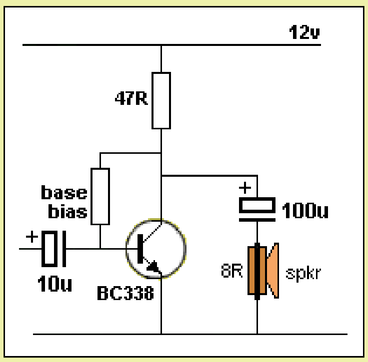




The circuit at the left shows an output stage as described in the video above, by the "Professor."
He tried to explain the base-biasing but failed.
In fact he did not know what he was talking about.
That's because the operation of the circuit is much more complex than you think.
The circuit has two features. The H-bridge design allows a known operating-point to be produced, even though the gain of the transistor may change from one device to another. Suppose the transistor is replaced with another having a higher gain.
The collector current will increase and more current will flow though the emitter resistor. This will produce a higher voltage across the emitter resistor and the difference between the base voltage and the emitter will be reduced.
This will turn the transistor OFF slightly and maintain the original conditions.
The second feature of the circuit is the electrolytic in series with the speaker. This allows **only** the AC portion of the waveform to enter the speaker and the cone is not "pulled" due to DC flowing though the voice coil.
However, the operation of the circuit is very complex, so we will explain it this way:
The design of the circuit starts by selecting the value of base bias resistors A and B. The resistors are chosen so that a voltage of about 0.7v is produced on the emitter. This allows the stage to be turned ON with about the lowest quiescent current. (This will produce a voltage of about 0.7 x 47 = 3.3v across the load resistor.)
To get 0.7v on the emitter, we need 1.4v on the base. This gives us the ratio of base bias resistor A and base bias resistor B.
The next thing we consider is the maximum current we want to flow through the load resistor. When the transistor is fully turned ON, this current can be as high as 230mA.
Let us allow the base current from the divider to be 100mA. The additional current will be created when the signal arrives and turns the transistor ON more.
Suppose the transistor has a gain of 100. This means the base current must be 1mA.
This will cause 100mA to flow through the 10R emitter resistor and produce a voltage of 1v.
The base voltage will be 1.7v.
The voltage across base bias resistor A will be 10.3v
The next design-feature to remember is this:
The current flowing through the base voltage-divider (resistors A and B) should be 10 times the base current to provide stable operation.
This means the current through base bias resistor A is 10mA.
The value of base bias A is: 10.3/0.01 = 10.3k
The value of base bias B is: 1.7/0.009 = 1.8k
Forget about the actual amplitude of the incoming signal.
What happens with the incoming signal is this:
The signal-peak gets converted by the 10u electrolytic to produce either a 2mA flow into the base or it cancels the 1mA flow to produce 0mA into the base.
The 100u electrolytic on the emitter prevents the emitter rising or falling and the stage operates just like the emitter is connected directly to the 0v rail.
When the incoming signal cancels the 1mA into the base, the transistor is turned off and the 47R charges the 100u connected to the speaker. This current flows through the speaker to shift the cone. A voltage develops across the electrolytic and energy is stored in it.
When the signal rises, up to 2mA flows into the base and the transistor is fully turned ON.
The energy in the electrolytic flows through the speaker and moves the cone in the opposite direction.

CONCLUSION:

The stage takes considerable current when "sitting around" and this is one of the disadvantages of a "Class-A" stage. If you want low quiescent current - use a class-B output stage.
The stage has a low input impedance (about 1k8) however it is driving an 8R load (the speaker) and this is a ratio of more than 100:1 and the stage is achieving a considerable "conversion."
You can call this circuit an INTERFACE, BUFFER, AMPLIFIER, DRIVER, POWER-AMPLIFIER, or MATCHER. It does all of these things.
The circuit must consume about "half-current" when "sitting around" so the incoming signal can increase the current to full-current or reduce it to almost zero, so the output signal is not distorted.
The "design-feature" involving the two resistors on the base can be changed to only allowing 2 or 3mA as "bleed current" so the input impedance is higher.
This will make the 1k8 resistor as high as 1.8 x 3 = 5.4k and the incoming signal will not be attenuated as much. The attenuation applies to both the rise and fall of the signal as this 1k8 (5k4) is directly across the signal.
It's all a matter of building the circuit and see how it performs as the transistor is at its limit of heat dissipation in this amplifier.
A simpler circuit is shown here. The base-bias resistor is chosen so that half-voltage appears on the collector and the transistor is self-biased so transistors with a slightly different gain will operate correctly.
This operation is commonly called "Mid-point operation" or "Q-point" operation. For maximum output the load resistor will need to be 8R, but this will create a current-flow that is more than the transistor will handle. That's why we use "class-B" (Push-Pull) output stages.



If you want to see the complex mathematics behind the circuit above, click **HERE** for a .pdf from a subscriber and teacher, Tom Wheeler thomas.wheeler@mcckc.edu. He has provided a mathematical assessment to show the power delivered to the speaker can be as low as 8% and in most cases it is not much higher than this value.
This is one more proof that "class-A" configurations are very inefficient.

Mr Wheeler is a lecturer at a tertiary college in Kansas City Missouri USA.
If you are interested in taking a course in electronics, you should investigate the courses available in a college near to you.
It is not easy to get through the jumble of course-names and terminology provided by colleges, technical colleges, institutes, Universities etc, but start by looking on the web and refer the to course-structure to see what topics are covered.
Mr Wheeler's college is **Metropolitan Community College in Kansas City, MO** www.mcckc.edu

Here is a brief listing from the colleges introduction:
The Metropolitan Community College Business & Technology Campus (BTC) is one of five MCC campuses that serve the greater Kansas City area. BTC offers both degree and certificate programs in Computer Aided Design and Drafting (CADD), Cisco Networking (CCNA/CCNP), Engineering Technologies (Mechanical/Electronic/Architectural/Civil), Environmental Health & Safety (EHSS), Electric Utility Lineman, Heating Ventilation and Air Conditioning (HVAC), Industrial Technologies (Instrumentation & Controls/Industrial Maintenance/Energy Efficiency), Solar/Photovoltaic Energy, Precision Machining, Welding, as well as degree completion programs designed for US military veterans and skilled trade apprenticeship completers. We are located at 1775 Universal, Kansas City MO, 64120; please visit our web site at www.mcckc.edu/btc, or call 816-604-5200 to arrange a campus tour.

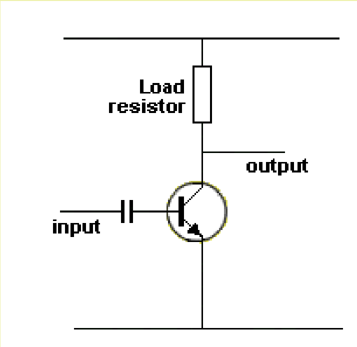
THE TRANSISTOR AS A BUFFER

We have already described the transistor as a **BUFFER** but previously we used different wording, such as **DRIVER**, **EMITTER-FOLLOWER** or **SINKING TRANSISTOR** or **SOURCING TRANSISTOR**.
In all these descriptions the transistor is doing the same thing. It is receiving a small current and/or a small voltage and delivering a larger current and/or a larger voltage.
All the terms are interchangeable and **BUFFER** describes a transistor that is placed between a **LOAD** that requires a high current and a **BUILDING BLOCK** that is only capable of delivering a small current.
A BUFFER or DRIVER TRANSISTOR is BUFFERING or JOINING the low impedance of the LOAD to the high impedance of a previous stage.
If you remove the buffer transistor and join the previous stage to the load, the result will be either very little

volume from a speaker, or a solenoid that does not operate or a globe that does not illuminate.
These devices do not work because the CURRENT is insufficient.
Many devices ONLY work when sufficient CURRENT flows.
That's what the DRIVER TRANSISTOR does. It increases the CURRENT.
Sometimes a transistor will increase the voltage from one section of a circuit to another.
This is called AMPLIFICATION and we do not use the word buffer. BUFFER only refers to amplifying CURRENT.

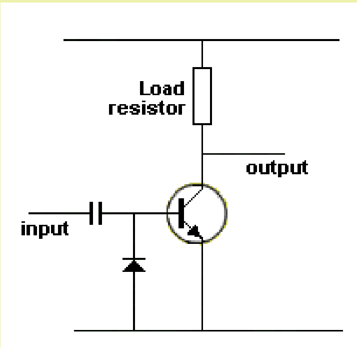
BIASING A TRANSISTOR

We have seen many different ways to bias a transistor and now we look at 3 and compare them.



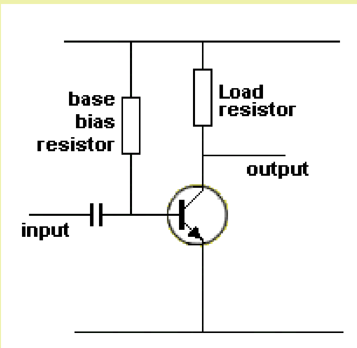
Transistor NOT biased

This transistor is not biased AT ALL. However it will work if the incoming signal is large.
The signal needs to provide all the energy to turn on the transistor and it only amplifies the positive portions of the waveform.
The amplifier is classified as "Class-C."

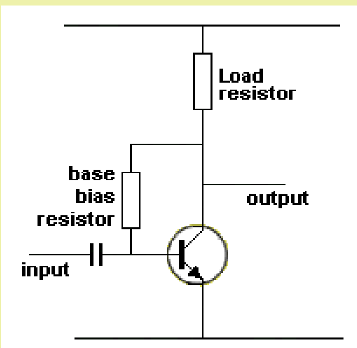


Diode discharges capacitor

To help discharge the coupling capacitor during the negative portions of the waveform, a diode can be included as shown. It comes into operation during the negative part of the cycle by "flipping over" and conducting when the negative part of the signal is less than -0.6v. All the waveform lower than -0.6v is passed through the diode and the capacitor is discharged during this portion of the signal.
A "Class-C" amplifier takes zero current when "sitting around" (quiescent current), and can be classified a very efficient, however in most cases it will produce distortion.



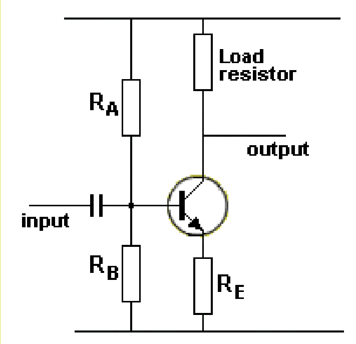
This circuit uses a base bias resistor between base and supply.
It is a "Class-A" amplifier.
This circuit will work successfully if the base bias resistor is chosen so the collector voltage is mid-rail.
However if you use another transistor with a lower or higher gain, the collector voltage will be higher or lower than for the previous transistor. In addition, the gain of the transistor will change slightly due to temperature and the collector voltage will alter.
This is not a good design as the collector voltage is not stable.



To make the operating-point of "Class-A" amplifier stable, the base-bias resistor is connected as shown.
If the gain of the transistor reduces due to temperature rise, the collector voltage will increase. This will increase the current through the base bias resistor and turn the transistor ON more and lower the collector voltage. It will not reduce to exactly the same voltage as before but the circuit will adjust to a fair extent.
If the transistor is replaced by one with a higher gain, the collector voltage will reduce. This is allow less current to flow into the base and turn the transistor off slightly and the collector voltage will rise. It will not rise to exactly the same voltage as before but the circuit will adjust to a fairly good extent.
This is called a "self-biasing class-A amplifier."

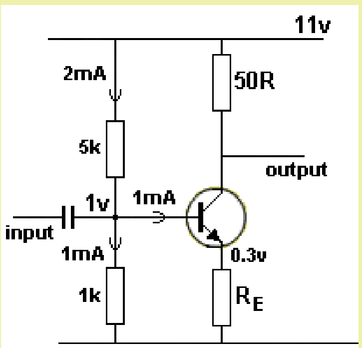
To get a better automatic biasing features as the circuit above, two additional resistors are needed and the circuit forms a bridge. (The word "bridge" comes from "Wheatstone Bridge" where 4 resistors are placed in a square to form a balancing network).
Ra and Rb form a voltage-divider to produce a fixed voltage on the base.
Re is a feedback resistor to create the stabilizing feature.

See: Emitter Feedback



Suppose the transistor gets warm on a hot day and looses gain.
The collector voltage will rise and the current through the load resistor will decrease. The current through Re will also decrease and the voltage across it will decrease. This means the voltage between the base and emitter will increase and the transistor will turn ON more to counteract the voltage-rise on the collector.

The value of Ra and Rb are calculated so that 10 times the base current "bleeds" through them. In other words, 10mA bleeds through Ra and 9mA through Rb so that 1mA goes to the base.
This is very wasteful, but let's look at why the bleed current needs to be 10x the base current.
There are two "design factors" in this type of circuit.
1. The bleed current through the voltage divider Ra/Rb is 10 times the current required by the base.
2. The values are chosen so that about 1v appears on the base. This allows the transistor to be turned ON and gives about 0.3v across the emitter resistor. This allows the emitter resistor to stabilize the stage and allows the transistor to turn ON and pull the output as low as possible when a large amplitude signal is delivered.

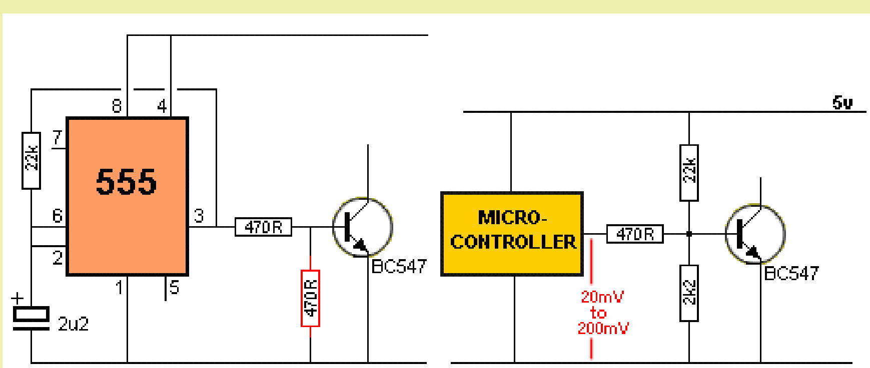


Let's see why the bleed current is 10 times that required by the base.
We will start with a bleed current of 2mA through Ra and 1mA through Rb with 1mA going to the base.
Suppose the transistor has a gain of 100. The current through the collector-emitter circuit will be 100mA and the value of Re will be 3R. The voltage across the load resistor will be 5v and the voltage on the collector will be 6v.
Suppose the transistor is replaced with one having a gain of 200. We already now the value of the load resistor (50R) and emitter resistor (3R) and the base bias resistors have the capability of delivering 1mA.
What will happen is this: The transistor will turn ON and because 1mA base current is available, it will allow 200mA to flow through the collector-emitter circuit.

The voltage across the emitter resistor will be 0.2 x 3R = 0.6v and the voltage-drop across the 50R will be 0.2 x 50 = 25v. We do not have 25v available (only 11v) and the transistor will turn ON to a point where it is fully saturated. This situation has occurred because the base voltage was able to rise so the base-emitter voltage is 0.7v. Since the transistor is taking only 0.5mA, the voltage across the 1k will theoretically be able to rise to 0.0015 x 1,000 = 1.5v
Now you can see why we want the base voltage to remain stable, so a transistor with a gain of 200 is not fully turned ON and the same collector voltage is produced for a wide range of gains.

BASE-EMITTER VOLTAGE

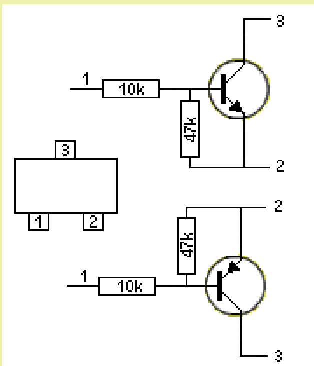
Up to now we have talked about the base-emitter voltage of a transistor as being about 0.55v to slightly more than 0.7v - depending on the transistor and how "hard" it is being turned ON.
But there is also a situation where a transistor must be TURNED OFF by providing a very low voltage on the base.
Sometimes you cannot provide 0v on the base due to the "control voltage" coming from another chip or a set of voltage-dropping resistors.
Some transistors (including surface-mount types) have a base-emitter voltage as low as 200mV, depending on the temperature of the transistor. As the temperature increases, the base-emitter voltage decreases and this will be quite a SURPRISE!
The following two circuits are typical examples:



The voltage on Pin 3 of the 555 (when it is LOW) can be as small as 100mV (depending on the SINKING CURRENT - the current flowing "into" pin 3 when a load is placed between pin 3 and the positive rail).
As this current increases to 200mA, the voltage on Pin 3 increases to 2.5v - WHEN IT IS LOW !!

Since this voltage is unknown and widely-variable, it is a good idea to add the extra 470R (shown in RED), to reduce the voltage on the base to a "cut-off" value.
When the chip is driving into the base of a buffer transistor, the current will only be very small when the output is low and to make sure it is below "cut-off" the extra 470R **HALVES** the base-emitter voltage - just tp make sure !!
In the second diagram, the voltage divider made up of the 22k and 2k2 produces a voltage of 0.5v on the base, however the inclusion of the 470R reduces this further and even though the output of the micro may be as high as 200mV when sinking a current such as 25mA, the base voltage will not go above 201mV. (In the circuit above the LOW voltage on the output of the micro will be almost zero - so, in this case, there is no problem).

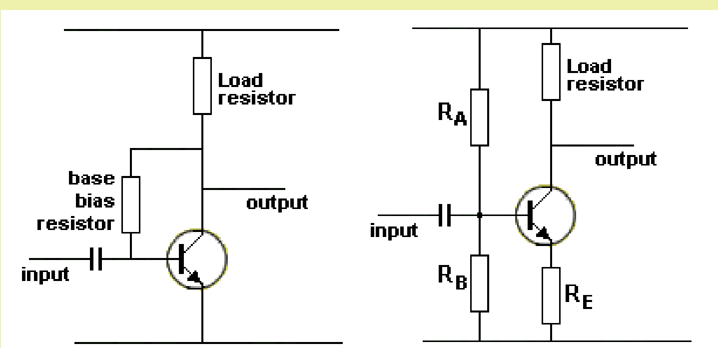
Transistors with internal Resistors



Transistor with Resistors

Some transistors have internal resistors. This includes small-signal transistors, power transistors, Darlington and surface mount devices. You must know if the transistor you are testing has internal resistors because the circuit will be lacking one or two resistors and you will wonder how it has been designed.
In most cases the values of the resistors will be the same as what you would use with a transistor not having internal resistors however if you are designing a new circuit, it is best not to include transistors with internal resistors - you may want to change the value and this is not possible with fixed values.
Some surface mount transistors and Darlington transistors have different values to those shown in the diagram on the left and you need to use a datasheet to determine the exact values. When testing these transistors they will appear to be faulty due to the internal resistors.
The resistor-values are chosen for circuits using the transistors with a medium to high collector current. They are not suited for stages where a very low collector current is required as the base resistor would be 47k to 100k.

Using a Transistor with a Higher Gain



Self Biasing **Bridge Biasing**

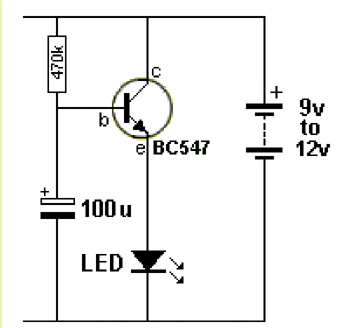
There are 4 main features of a transistor.
1. Its power-handling capability,
2. Its voltage-rating,
3. Its maximum frequency,
4. Its gain.

What happens if you replace a transistor with one having a higher gain?
The operating point (the "Q-point") will adjust in the Self-Biasing circuit but if the new transistor has a much-higher gain, the collector voltage will be lower.
The Bridge-Biasing arrangement will maintain a more-constant collector voltage when the transistor is replaced with one having a higher gain.

In other words, the **quiescent-point** or **operating-point** (or mid-point for the collector-voltage) of a Self-Biasing or Bridge-Biasing circuit will self-adjust when the gain of the transistor alters. But a higher gain transistor will allow the collector voltage to drop closer to 0v when the incoming signal delivers the high portion of the waveform. The result will be a slightly higher output because the output will go to a lower value than before.
The opposite will occur with a transistor having a lower gain.
See self-biased transistor and biasing for details on how to design the two stages.

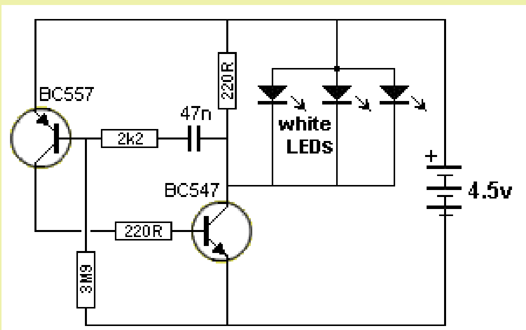
Using a Transistor as a CURRENT LIMITER

The circuit produces a delay of a few seconds due to the **TIME DELAY** circuit (made up of the 470k and 100u) taking time to charge the 100u. The transistor is an **EMITTER FOLLOWER** and the emitter rises at the same rate as the base but is about 0.7v less than the base.
The circuit does not have a CURRENT LIMITING resistor in series with the LED or in the collector circuit because the transistor can only allow a current between the collector and emitter terminals that is 100 to 200 times more than the current entering the base and it effectively becomes a resistor. If the transistor has a gain of 200, it will be 470,000/200 = 2350 ohms. This will deliver 10/2350 = 4mA.



10 Second Delay

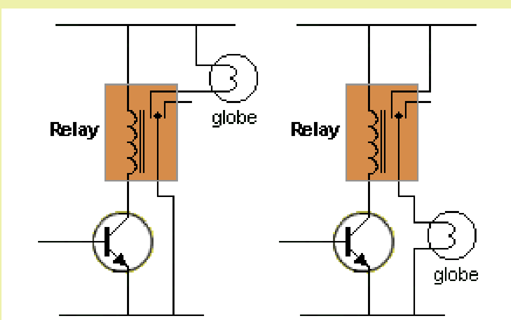
Another way to explain the circuit is to work out the current entering the base. The voltage across the 470k resistor will be about 10v max for 12v supply and the current will be 0.02mA.
The emitter current will be 0.02 x 200 = 4mA max.
The transistor is acting as a **CURRENT LIMITER**.



BIKE FLASHER

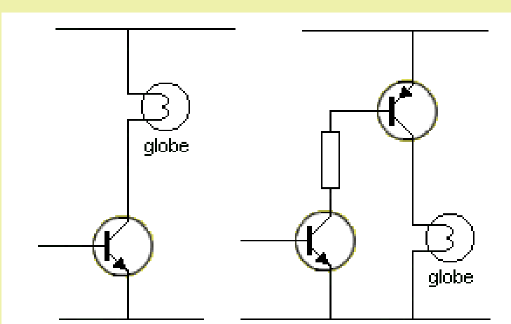
You will notice the absence of a current-limiting resistor on the white LEDs.
There are two reasons why this resistor can be eliminated.
The BC547 transistor can only pass about 100mA and three white LED can easily accept 30mA each. The LEDs need to be tested to make sure they all have the same "Characteristic Voltage" of 3.3v or 3.5v so they illuminate equally.
Secondly, they are only illuminated for a very short period of time and your eye extends the effect by a feature called PERSISTENCE OF VISION. This means they will never get overheated.
Even though the transistor is seeing about 15mA into the base, it will still only allow 100mA collector current to flow and it is acting as a CURRENT LIMITER for the LEDs.

TRANSISTOR REPLACES A RELAY



Globe connected HIGH **Globe connected LOW**

You need all the previous discussions to understand how a transistor can be used to replace a relay.
A replacement can only be used in some cases.
The main advantage of a relay is its ability to completely isolate the driving circuit from the load.
That's the main reason why it is used. A transistor does not provide this isolation.
However a relay has a limited life and if the circuit is constantly switching on and off, the relay will soon fail.
There are a number of factors that need to be considered before a replacement can be made.
The first is the way the load is connected. It can be connected "HIGH-SIDE" or "LOW-SIDE."



LOAD connected HIGH **LOAD connected LOW**

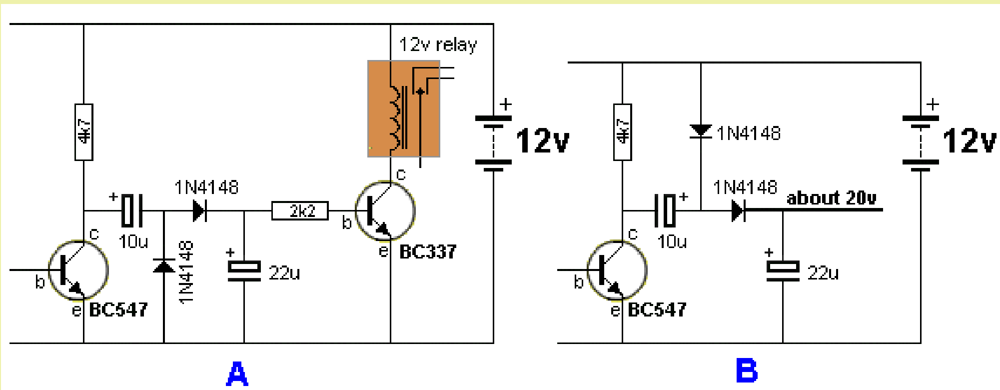
In other words, the load can be connected between the positive and relay to create HIGH-SIDE. (the other terminal of the relay is connected to 0v.)
Or it can be connected between the relay and 0v to create LOW-SIDE. (the other terminal of the relay is connected to positive rail.)
This will determine how the transistor circuit is designed.
The other important factor is the current-capability of the transistor. It must be able to handle the current and it must be driven into saturation so that the least voltage is lost across the collector-emitter circuit.
Turning the transistor ON and OFF quickly will also reduce the temperature of the driver transistor.

THE DIODE PUMP (CAPACITOR INPUT PUMP)
Also called a CHARGE PUMP.
And the VOLTAGE DOUBLER

There are two circuits in this discussion that look very similar but produce different results.
Circuit A is called a DIODE PUMP or CAPACITOR-INPUT PUMP or CHARGE PUMP and it produces an output voltage that is never higher than rail voltage.
Circuit B is called a VOLTAGE DOUBLER. However it can be called a CAPACITOR-DIODE CHARGE-PUMP

or CHARGE PUMP. It produces a voltage higher than rail voltage.

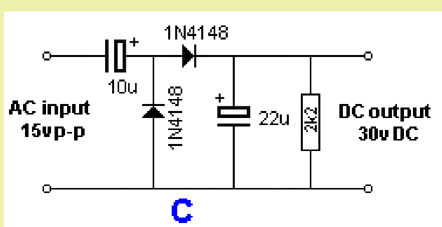
Circuit A is basically designed to activate a relay when the voltage across the 22u rises above 0.7v. Only an AC signal will pass through the 10u and when the BC547 turns off, the 4k7 pulls the positive lead of the 10u towards the positive rail. This causes the negative lead to rise too and a voltage appears at the join of the two diodes. The lower diode has no effect at the moment but the upper diode passes this voltage to the 22u and the electrolytic begins to charge. The 10u also charges. The BC547 is designed to turn on after a short period of time and it pulls the positive lead of the 10u towards the 0v rail. The 10u has a small voltage across it at the moment and the negative lead goes below the 0v rail. As soon as the lead goes -0.7v, the lower diode starts to conduct and it discharges the 10u. Only a small voltage of about 0.9v will be left in the 10u and the BC547 is now designed to turn off. The 4k7 pulls the 10u towards the positive rail and the 22u gets a further small amount of charge. As soon as it reaches 0.7v, the BC337 turns on and energises the relay. The 2k2 allows the 22u to charge to a slightly higher voltage than 0.7v so that the relay remains activated a short period of time after the signal from the BC547 has ceased.
This circuit coverts an AC signal into a DC voltage.



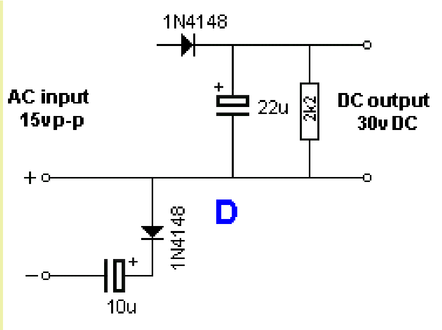
Circuit B is a VOLTAGE DOUBLER. The two circuits appear to be very similar. The component values are the same. We have reversed the 10u and placed the lower diode above the other diode.
The operation of the circuit is completely different.
When the BC547 turns ON, the 10u charges via the top diode. When the transistor turns OFF, the 4k7 pulls the left lead of the 10u towards the positive rail. This pulls the negative lead up and it rises above the 12v rail by about 11v. This puts 12v plus 11v on the left lead of the second diode and it passes this voltage to the 22u. The 22u charges to about 20v.

A practical version of this circuit is in our **50 - 555 Projects** eBook. Battery Charger

A 12v battery can be used to charge another 12v battery by using a voltage doubler circuit and although the full voltage is not required, the circuit automatically adjusts and charges the battery. When the battery is removed, the output voltage rises to about 18-20v.
Circuit C is a **DIODE PUMP** (**VOLTAGE DOUBLER**) from an AC source (such as the "Mains").

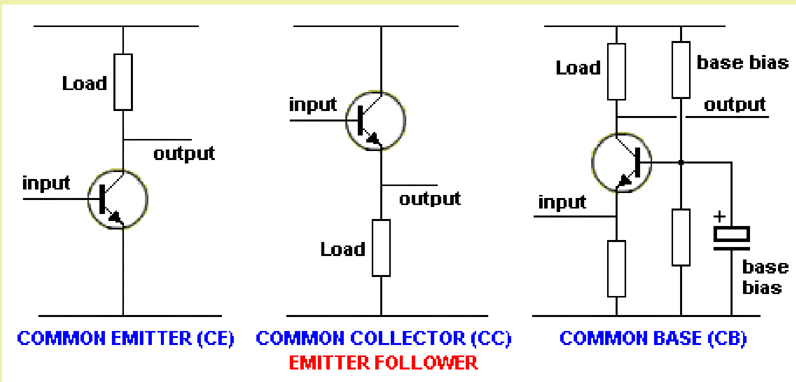


The circuit takes a number of cycles to get up to full output voltage and this is how it works:
The input voltage rises and because the 22u is uncharged, the 10u starts to charge as soon as the 0.6v across the top diode is reached.
The 10u charges to about 10v and puts about 5v on the 22u.
When the AC reverses polarity, the top diode does not have any effect but the lower diode becomes forward biased and it allows the 10u to charge to about 15v.
When the AC reverses again so that the top input becomes positive, the 10u already has 15v on it and the AC adds another 15v.
This means the positive lead of the 10u is 30v above the lower rail and it charges the 22u to about 15v.
This happens a few more times and eventually the 22u gets charged to 30v (minus 2 x 0.6v diode drops).
After 5 or more cycles, the 22u has about 30v across it and the 10u keeps "topping up" the voltage as follows:
Say the 10u has 14v across it, when the top input of the AC becomes negative, the 10u immediately jumps to a position below the 0v rail and the diode connected to the 10u allows it to be charged to 15v, (the top diode effectively comes "out-of-circuit" as shown in diagram D:

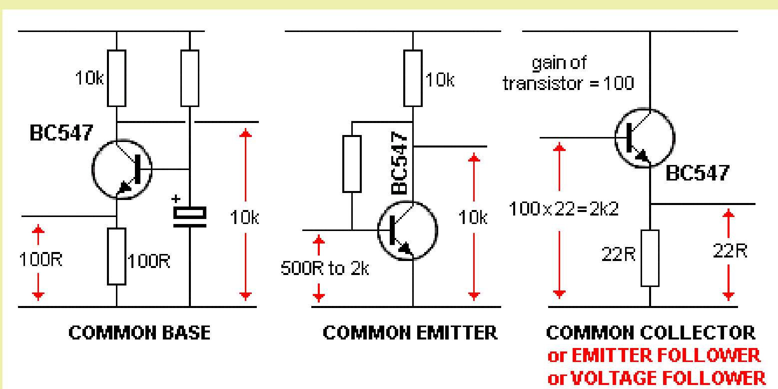


SUMMARY

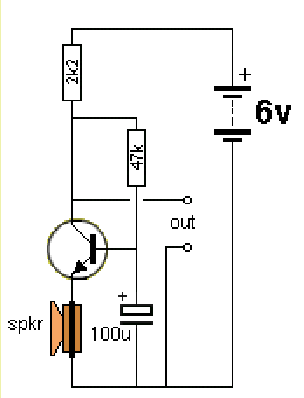
Here is a summary of the features of the three basic ways a transistor can be connected:

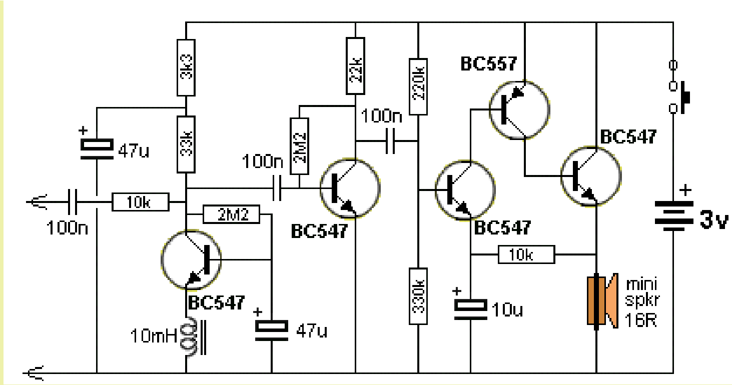


Characteristic	Common Emitter	Common Collector	Common Base
Input Impedance	Medium	High	Low
Output Impedance	High	Low	Very High
Phase Angle	180^o	0^o	0^o
Voltage Gain	Medium	slightly less than 1	High
Current Gain	Medium	High	Low
Power Gain	Very High	Medium	Low

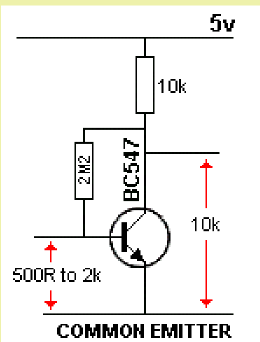


You can see the input impedance of a **COMMON BASE** stage is equal to the resistance of the emitter resistor it is designed to interface (connect) a low impedance device to the circuit. This is normally very hard to do as the speaker or inductor may be only 8 to 50 ohms. Trying to connect an 8 ohm device to the input of a 500R stage produces a lot of mis-match and produces high losses. The common base arrangement does this very well and that's why it is so useful.



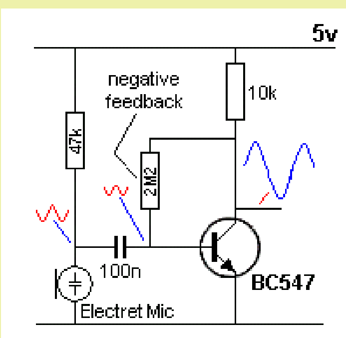


The **COMMON EMITTER** arrangement needs more explanation as the summary above suggests the input impedance is about 500R to 2k.
We have already explained (in **Fig 11**) that a transistor with a gain of 200 will produce a voltage amplification of about 70 in this type of circuit. The reason is the 2M2 base-bias resistor.
It is acting as a feedback resistor and is acting AGAINST the incoming signal.
For example, if the incoming signal is rising, the collector voltage will drop and this will be passed through the base-bias resistor to deliver less current to the base. This is opposing the current being delivered via the signal and that's why it is called NEGATIVE EFFECT or NEGATIVE FEEDBACK. Thus the transistor cannot produce the output amplitude you are expecting.



NOTE:

The value of 500R to 2k2 for the input impedance of a common-emitter stage is very misleading.
You would think the input is like driving into a 2k2 resistor. But this is not the case. Placing a 2M2 between the base and 5v rail will turn the transistor ON fully. The 2uA via the 2M2 is sufficient to turn the transistor ON. This is obviously nothing like driving into a 2k2 and you should avoid thinking about the input as a low value as it only applies when the transistor is heavily conducting.
Transistors will respond to a fraction of a microamp and you should think of them as having very sensitive inputs.

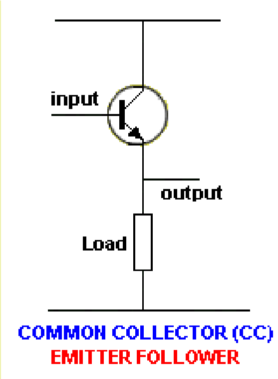


But the question at the moment is this: **What effect does the input impedance have on an incoming signal?**
When a transistor is **lightly loaded**, as shown in the circuit on the left, a very small current into the base will produce an output waveform. It is too complex to talk about input impedance of 500R to 2k. This value does not help us explain the operation when lightly loaded.
The easiest way to talk about the input impedance is to discuss the current entering the base when a signal is applied, by looking at the "voltage waveform". The voltage (signal) on the base can be viewed with a CRO (Cathode ray Oscilloscope) and although we don't know the value of the associated current, the voltage waveforms though the circuit produce an increase of about 70 and this is adequate in most cases.

We see the waveform produced by the electret mic is reduced when it passes through the 100n capacitor. This reduction is due to the impedance (resistance) of the 100n capacitor and also the input impedance of the transistor. Rather than trying to work out all these complicated values, the easiest way to create the required amplitude on the output of the stage is to reduce the 47k. When this value is reduced, the output of the electret mic increases. Talking Electronics uses only high quality electret mics and they require a load resistor of 33k to 68k for 5v supply. Some junk electret mics need 10k or as low as 2k2 and that's why this resistor can range from 2k2 to 68k.
The electret mic will produce an output of about 30mV and the waveform on the base will be about 20mV. With a gain of 70, the collector waveform will be 1400mV.
When a transistor is required to pass a high collector current, the current entering the base is considerably higher than discussed above. When the collector current is approaching the maximum for the type of transistor, a transistor with a gain of 200 will not produce this high gain. The gain will be considerably LOWER. It may be 100 or 70 or even 50. This is why a high input current is needed and it will appear as though the transistor has a low-to-medium input impedance.

Common-Collector

The **COMMON COLLECTOR** stage is also called the **EMITTER FOLLOWER** stage.
The input is the base and the output is the emitter. The collector is connected to the supply rail.
This stage is classified as having a HIGH INPUT IMPEDANCE because the transistor allows you to deliver a high current to the load by supplying a very small current into the base.



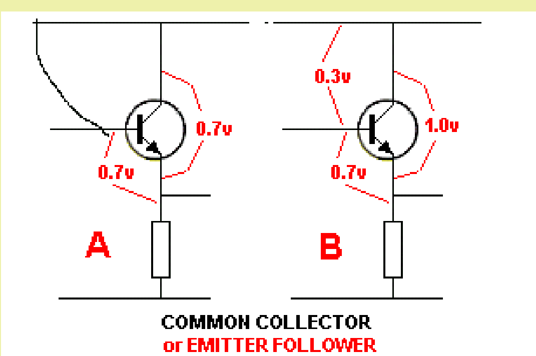
In other words the transistor amplifies your effort by about 100 times.
This is due to the gain of the transistor.
When you are doing this, the load appears to be a much-higher value of resistance as the transistor multiplies the resistance of the load by a factor of about 100 times.
That's why the circuit is classified as having a HIGH INPUT IMPEDANCE.

How does the Common-Collector circuit work?

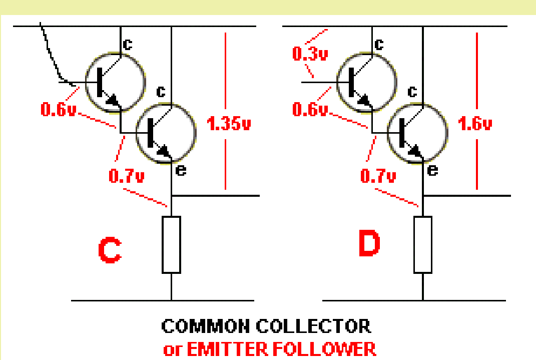
Firstly we will assume you have a voltage of 10v on the base and can deliver 3mA into the base.
What is the voltage on the emitter and how does appear on the emitter?
The transistor amplifies the 3mA by about 100 times and this produces 300mA through the collector-emitter junction. This current flows through the emitter resistor and say it produces 12v across the resistor.
This voltage is higher than the base voltage and this cannot happen. What happens is the current increases and the voltage increases on the emitter resistor until the voltage is 0.6v LESS than the base voltage. At this point the transistor turns off a small amount and the current reduces so the voltage reaches EXACTLY 0.6v less than the base. That's how the voltage on the emitter is 0.6v less than the base. If you raise the voltage on the base, the emitter voltage will rise too. If the base voltage is lowered, the emitter voltage will reduce.
The emitter voltage FOLLOWS the base voltage and that's why we call the circuit **EMITTER-FOLLOWER**.

A "technical" person in a forum said: "Normally don't use a bipolar transistor in common collector configuration for switching loads." This needs some explaining.
If you have an input voltage that rises from 0v to full rail voltage, you can use an emitter-follower circuit.
An emitter-follower is called an IMPEDANCE MATCHING CIRCUIT.
What this means is the transistor is increasing the resistance of the load by 100 times and the previous stage thinks it is delivering to a load that is 100 times higher in resistance.
You could use a common-emitter stage and the result would be the same when you compare the maximum currents but the common-emitter stage will turn ON when the voltage on the previous stage is about 1v and this will cause distortion in an audio amplifier.
If you are driving a motor, an emitter-follower stage will allow you to regulate the speed since the input voltage rises from 0v to rail voltage and the motor will respond to this.
If you are driving a relay, a common-emitter stage will speed up the timing because it will react to the voltage when it has risen about 1v. An emitter follower stage will turn on the relay when the voltage has risen to about 80% of rail voltage.

Common-Collector Problems



Designing a **COMMON-COLLECTOR** stage has a number of problems. The main one is the voltage dropped across the collector-emitter terminals of the output transistor.
This transistor is also called an **EMITTER-FOLLOWER** and it is always going to have a minimum voltage-drop of 0.7v when the base is at rail voltage. But in most cases the base will be less than rail voltage by at least 0.3v. This means the voltage across the transistor will be 1v.
A transistor in a common-emitter configuration will be about 0.2v. This means the common-collector arrangement will be 5 times hotter (approx) and the load will get 0.8v less voltage.



The situation gets worse when a Darlington pair is connected as a common-collector output. The voltage across the two transistors will be a minimum of 1.35v and will normally be **more than** 1.6v.

Figs E and **F** show some solutions to driving a load with the most-efficient design.

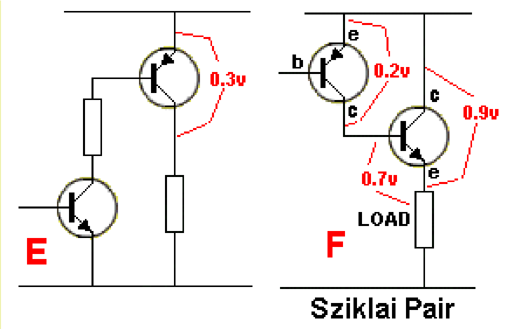
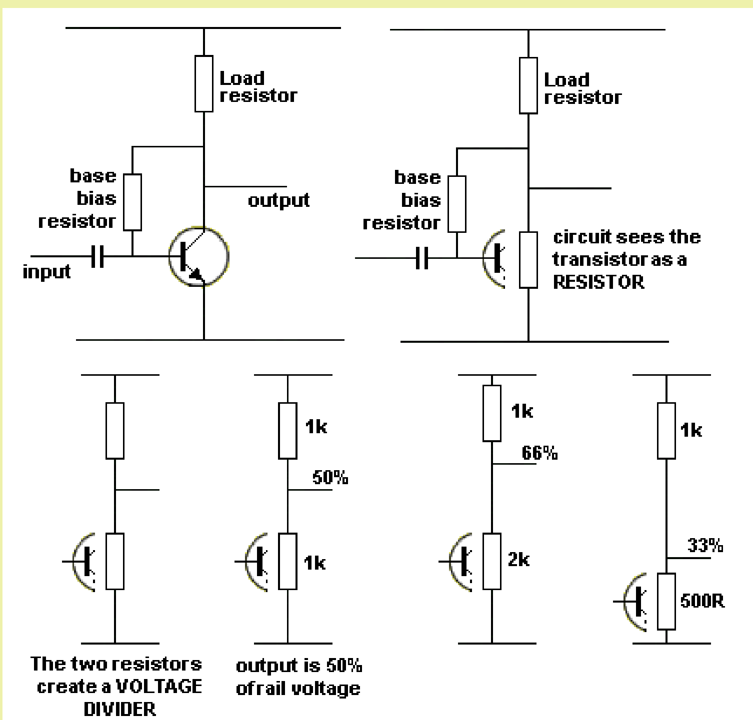


Fig E is called a NPN/PNP pair and **Fig F** is a Sziklai Pair.
Only the important voltage-drops have been shown and these values will be higher for some transistors and will also increase as the current increases.
This is just an example of the minimum values to expect.

THE TRANSISTOR AS A VARIABLE RESISTOR

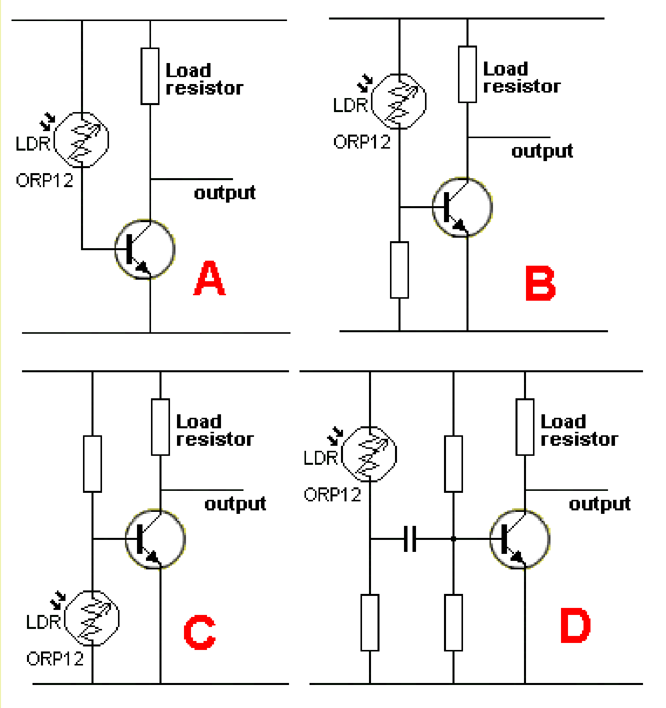
Many circuits use a transistor as a variable resistor but this fact is never mentioned.
There are many ways to look at how a transistor is operating and one of them is to see the transistor as a VARIABLE RESISTOR.
In fact, that is what the transistor is doing in 99% of circuits. It is acting as a VARIABLE RESISTOR.
In a digital circuit, the transistor is turning OFF completely then turning ON fully. This is equivalent to a very high-value resistor in the first instance, then a very low-value resistor.
In an audio circuit, the resistance of the transistor is reducing then increasing. It is working in series with a LOAD resistor and the voltage at the join of these two is the OUTPUT of the stage.
For a common-emitter stage, when the resistance of the transistor decreases, the output is LOW (meaning the output voltage is small) and when it increases, the output is HIGH.
The transistor and the load resistor form a VOLTAGE DIVIDER and the voltage at the join of these two components depends on the value of the transistor.
When the resistance of the transistor is equal to the load resistor, the voltage at the join will be 50% of the supply. When the resistance of the transistor is twice, the voltage will be 66% and when it is half, the voltage will be 33%.



The transistor as a VARIABLE RESISTOR

THE LIGHT DEPENDENT RESISTOR

The Light Dependent resistor (LDR) is a variable resistor. Its resistance varies according to the amount of light it receives.
It's a very simple component and can be connected directly to a transistor so the change-in-resistance of the LDR can be amplified about 100 times.
Even though this arrangement is very simple, it takes a lot of understanding to design a suitable circuit and see HOW IT WORKS.
An LDR has a resistance of about 300k when in total darkness and as low as 200 ohms in bright light.
But it is very difficult to turn a light ON and OFF to get this extreme range in resistance.
In most cases the change will be a LOT LESS.
The actual value of resistance will depend on the type of LDR and the light-conditions.
There are 4 ways to connect an LDR to a transistor:



How do you connect an LDR?

Circuit A only works when the light drops to zero.
Circuit B produces a LOW on the collector when light is detected.
Circuit C produces a HIGH on the collector when light is detected.
Circuit D detects a CHANGE in light conditions.
There are **TWO WAYS** to see how an LDR works.
1. It delivers a **CURRENT** according to its resistance.
2. It it part of a **VOLTAGE DIVIDER** when connected in series with another resistor.

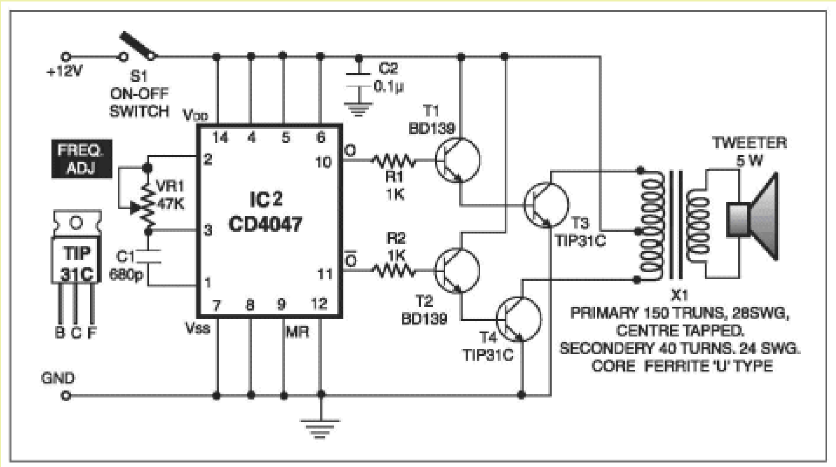
In the first circuit, **Circuit A**, the LDR acts as a current-limiting device - or more-accurately A CURRENT-DELIVERING DEVICE and the output will be HIGH when the LDR does not receive any illumination, providing the LOAD resistor is a small value.
This is the reason: The resistance of the LDR will be 300k and the transistor will effective reduce this value to 1k and produce a voltage divider of 1k:load resistor. If the load resistor is 470R, the voltage on the output will be 66% of rail voltage.
When light falls on the LDR, it resistance decreases and if it reduces to say 5k, the transistor will convert this to 5,000/200 = 25 ohms and the output of the circuit will go LOW.
If the LOAD resistor is 10k, the LDR in dark conditions will provide a resistance of 300k and the transistor will convert this to 1k. The ratio of 1k:10k will mean the output of the stage is LOW for both dark and light conditions.
Thus the resistance of the LOAD resistor must be selected for the light conditions experienced by the LDR and the gain of the transistor.
Circuit B effectively makes the stage less sensitive to changes in illumination on the LDR.
The base resistor allows some of the current supplied by the LDR to flow to the 0v rail. This means the transistor gets only some of the current and more light has to shine on the LDR for the circuit to change states.
The actual current "bled-away" by the base resistor is very complex to determine and requires mathematics beyond the scope of this discussion.
However we can say the base resistor is normally between 100k and 1M and the LOAD resistor between 1k and 10k. In this circuit, the output goes LOW when the LDR receives illumination.
In **Circuit C**, the output goes HIGH when the LDR detects light.
The base-bias resistor is normally between 2k2 and 10k and the LOAD resistor between 1k and 10k.
This gives an enormous range of operating parameters (current taken by the circuit) and we can simplify the discussion by saying this:
The base-bias resistor forms a voltage divider with the LDR and when the voltage on the base is 0.55v, the transistor starts to turn OFF. At 0.45v the transistor is OFF. Light must be directed onto the surface of the LDR and it will reduce the effective resistance on its terminals. The intensity of the light to turn the transistor OFF will depend on the value of the base-bias resistor.
In **Circuit D**, the output will change when a hand is waved over the LDR. This causes the resistance of the LDR to increase then decrease.
The voltage at the junction of the LDR and the resistor to 0v will fall the rise again.
The transistor can be biased ON slightly or OFF via the two resistors on the base and when the voltage on the "output of the LDR" changes, the change is passed through the capacitor to change the state of the transistor.

HIGH IMPEDANCE

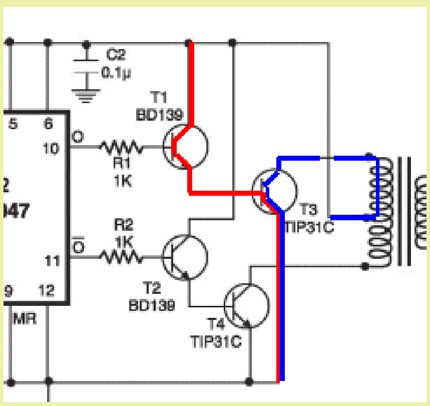
If you want to go into a more-complex discussion, here it is:
The LDR needs to feed into a HIGH IMPEDANCE stage because it is classified as a high impedance device. It is only capable of passing (delivering) a small current, that's why it is called a HIGH IMPEDANCE component.
The transistor is called a BUFFER (or amplifier) as it amplifies the current.
The transistor is a BUFFER because it "joins" the low-current capability of the LED to the high-current requirement of a LED - just like the buffer at the end of a carriage on a train or the old-fashioned bumper on a car (containing springs).
A HIGH IMPEDANCE stage accepts very small currents and amplifies them.
If the LDR is connected to a low-impedance stage, the current it is capable of delivering will enter the transistor and the collector voltage will change VERY LITTLE. This is because the transistor needs a higher input current. The LDR is not capable of delivering this high current and the output of the circuit will NOT CHANGE

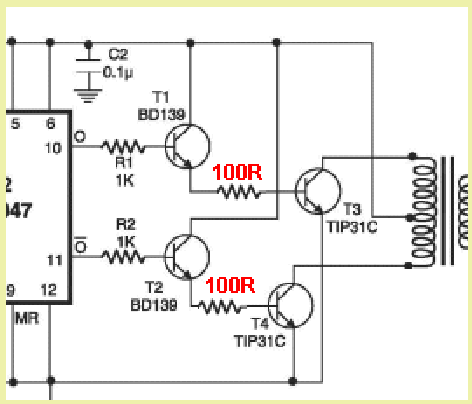
or only change a VERY SMALL amount. A low-impedance stage has say 2k2 resistor on the base and 100R on the collector.
We use the word "IMPEDANCE" because if we measure the values with a multimeter, the "resistance" of the junction of the transistor is also measured and since this is a diode, its "resistance" changes according to the current flowing and is not a fixed value. Whenever a capacitor, diode or coil is included in the circuit we are measuring, we call the value an impedance to show that we are taking into account the inclusion of the other component(s).

SHORT CIRCUIT CURRENT / shoot-through current



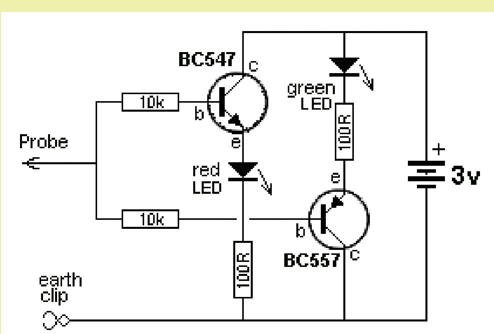
Here is one of the major hidden problems when designing a circuit.
It's called a **SHORT CIRCUIT current** or "**Shoot-through**" current and occurs when two transistors are directly connected together as shown in the output section of the circuit on the left.
The chip can deliver about 10mA to the base of the top transistor and if the transistor has a gain of 100, the collector-emitter current will be 1AMP !!





This current will also flow through the lower transistor and is WASTED CURRENT. It creates an almost SHORT-CIRCUIT across the supply rails.
The solution is to add a low value resistor such as 100R to limit the current.

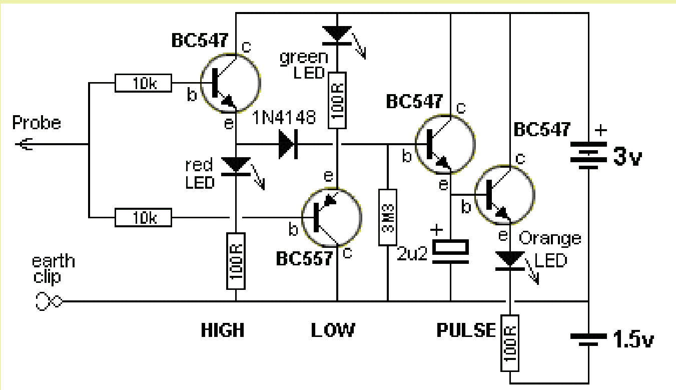
NO CURRENT . . .



No ON-OFF switch needed

In all the circuits we have discussed, there is a small quiescent current flowing when the circuit is "sitting around" doing nothing - called the "Quiescent Current." This current is the biasing current and is needed to turn the transistor(s) ON slightly so it will amplify the smallest signal. If the transistor is not turned on slightly, it will not amplify signals smaller than 600mV as the base must see a signal more than 550mV for the transistor to start to turn on.
The circuit above is a LOGIC PROBE and will detect a HIGH or LOW on a digital circuit where the waveform is higher than 2.5v. This circuit can be in a state of "cut-off" (not conducting) and the input amplitude will turn the circuit ON.
The clever feature of this circuit is the lack of an ON-OFF switch. The circuit takes no current when not detecting a waveform because the voltage-drops across the semiconductor junctions is greater than 3v (and the supply is 3v).
To turn on a transistor, the voltage between the base and emitter must be greater than 550mV. But if the voltage is less than 550mV, absolutely no current flows through the junction.

The same applies with the characteristic voltage of a LED. For a red LED, the characteristic voltage is 1.7v but if the voltage is less than about 1.5v, no current will flow. The same applies to a green LED. Its operating characteristic voltage is 2.1v to 2.3v but when the voltage less than 1.9v, no current will flow.
The current-path for the circuit in "idle mode" is through the green LED (1.9v), 100R, the emitter-base junction of the BC557 (0.55v), through two 10k resistors, the base-emitter junction of the BC547 (0.55v), the red LED (1.5v)100R to the 0v rail.
When the minimum voltages are added we get 4.5v. But the supply is only 3v and thus it is not high enough to meet all the minimum junction voltages.
Thus no current will flow through the circuit when "sitting around."

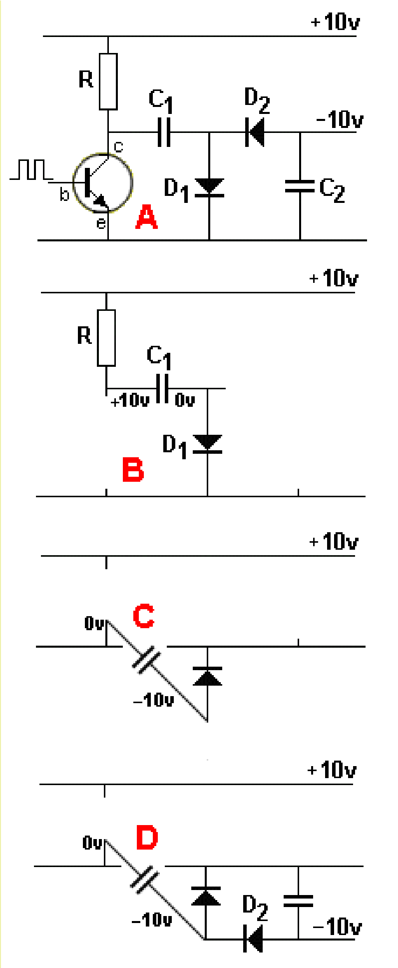


LOGIC PROBE with HIGH, LOW and PULSE

The same "cut-off" condition applies to the **Logic Probe** circuit above. But this time an orange LED is added to the circuit.
The Pulse LED is connected to the HIGH section of the circuit and its illumination is extended by the inclusion of the 2u2 electrolytic so a brief pulse can be observed.
To extend the illumination of the orange LED, we need to charge this electrolytic.
But an electrolytic needs a lot of current to charge it quickly and the input of a Logic Probe is HIGH IMPEDANCE - in other words it has no "charging capability."
This means the pulse from the input needs a lot of assistance to charge the electrolytic.
To do this we have used 2 transistors. The first and third transistors form a SUPER-ALPHA pair and this provides a lot of "strength" (current) to charge the electro.
But we can only charge a very **small-value** electro, so we need another transistor to ELECTRONICALLY increase the value of the electro about 100 times. That's the purpose of transistor four.
We now have the circuit we need to extend the illumination of the pulse LED.
But when all these components are connected, we have run out of voltage to illuminate the LED with a HIGH of 3v.
To solve this problem we have added a single 1.5v cell as shown in the diagram. The emitter of the 4th transistor will have about 1v on it (with reference to the 0v rail) and the lower lead of the 100R will have minus 1.5v (with reference tot he 0v rail). This means the orange LED and 100R will see a voltage of 2.5v. This is sufficient to illuminate the LED.

Producing a Negative Voltage

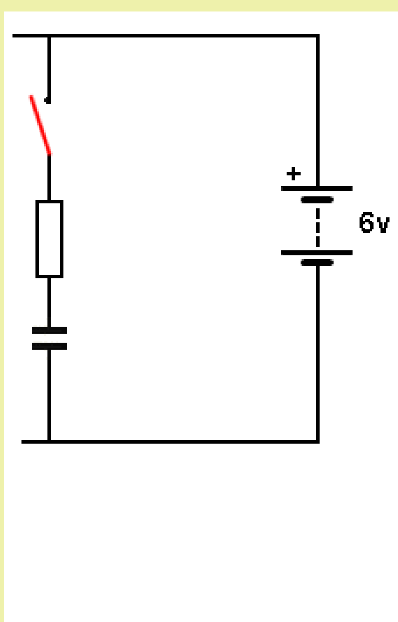
A negative voltage can be produced from a positive voltage with a circuit called a DIODE PUMP or DIODE CHARGE PUMP. In its simplest form it is called a VOLTAGE INVERTER.
To create the negative we use the circuit on the left, as shown in fig **A.**
The transistor is fed a signal. It can be a square-wave, sinewave or audio waveform. All it has to do is turn the transistor ON and OFF and the voltage on the collector will range from nearly 0v to nearly rail voltage.
This waveform is passed to the voltage-doubling circuit via a capacitor. Let's see how the two capacitors and two diodes produce a negative voltage.
The cycle starts with circuit **B**. The transistor is OFF and capacitor C1 is connected to the positive rail via the resistor **R**. It charges to about 10v via the resistor and diode D1(actual voltage will be about 9v).
When the transistor turns ON, the left lead of the capacitor will drop to the 0v rail and the right lead will drop 10v BELOW the 0v rail.
The diode will "flip over" but it will not conduct when the anode lead is negative.
This is the most important part of the discussion. The right lead of the capacitor produces the NEGATIVE VOLTAGE. This is shown in circuit **C**.
In circuit **D** we connect D2 and the cathode of D2 is negative. This will make D2 conduct and the anode of D2 will also be negative by about



8v to 9v and this will pull the lower lead of C2 DOWN by a voltage of about 8v to 9v and create the negative output of the circuit.
We have shown the output to be 10v, but each diode will lose (drop) about 0.6v and the capacitor will not charge fully so the output will be about 8v.
When the transistor turns OFF, the left lead of C1 will rise to about 10v and because the capacitor is fully charged, it will not charge any more. It has done its job.
However, if the output of the supply delivers a current, the output voltage will fall and the capacitor will not have 10v across it. In this case is will charge a small amount and restore the output to -10v.

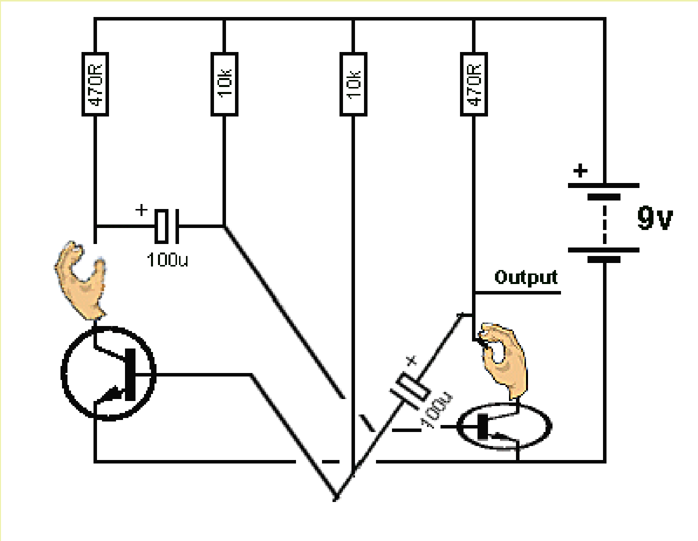
NEGATIVE VOLTAGE

Many circuits produce a negative voltage or negative spike at some point in the circuit. In other words the voltage will be LESS than the 0v rail of the circuit. The circuit above is a good example and this negative voltage is stored in the second capacitor.
But some circuits do not store the effect and and the generation of the negative voltage is not realised. That's why you have to know how a negative voltage can be generated, so you can be aware of its generation.
It is due to the presence of a capacitor and the animation below shows how a capacitor can produce a negative voltage:



When a charged capacitor is lowered from a "high" position in a circuit, the positive lead may be lowered by say 3v. This means the negative lead will be lowered by 3v. (we are assuming the capacitor can be lowered and is not directly connected to the 0v rail). The result is a voltage on the negative lead that is "less than" the 0v rail.
Generally, this "spike" or voltage is not obvious and the voltage "stored in the capacitor" does not "go negative." That's why this effect may be missed in a circuit.

You can see the electrolytic produces a NEGATIVE VOLTAGE on the base of a transistor in the following animation, when the transistors change state:

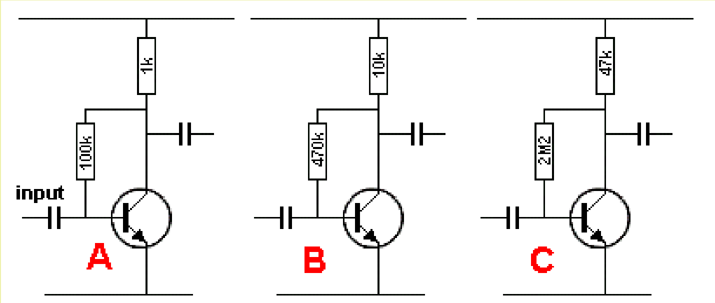


Many transistors don't like a negative voltage on the base and they can be destroyed due to this effect if the supply voltage is vey high. And you will wonder why the transistors are being destroyed !!

THE POWER SUPPLY

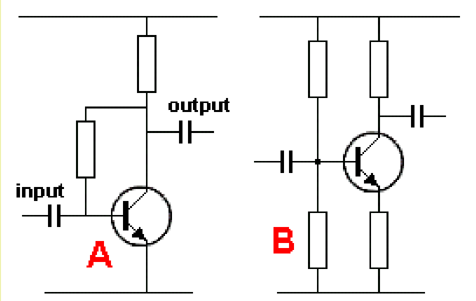
We are not going into designing a power supply but want to cover one of the mayor misconceptions about a power supply:
A lot of readers to a Forum have asked: **I want a 20mA power supply, but all I can find is a 100mA supply. Will this BURN-OUT my project?**
Answer: If the project is correctly designed and requires 20mA when connected to a 12v power supply, it will take exactly 20mA and not burn out.
If the project requires 100mA, it can be connected to a 100mA power supply and it will work correctly.
If the project requires 200mA and is connected to a 100mA power supply, the power supply will deliver 100mA (and maybe a little more) but the voltage will start to fall when the full 200mA is required and the power supply will get very hot. The project will not be damaged but it will not perform to its full capability.
See 200 Transistor Circuits: 1-100 101 - 200 for projects on Power Supplies.

RE-CAPPING



Let's go over a number of design-features we have mentioned in this discussion.
The three diagrams on the left show a self-biased transistor with approx half-rail voltage on the collector.
What is the difference between circuits **A**, **B** and **C**?

We have shown that passing the energy (the size of the signal) from one stage to the next, depends on the value of the load resistor. A low-value resistor will pass more energy. Thus circuit **A** will pass more energy.
We have also shown the value of the coupling capacitor (this is the same in all circuits above) and the value of the base-bias resistor determines the amount of energy that will be transferred.
Circuit **C** will have the least effect on attenuating the signal because the transistor is turned on via the smallest amount of base current (the highest-value base-bias resistor) and thus the input impedance is the highest.
The third factor to consider (for battery operated devices) is quiescent current. Circuit **C** takes the least current.
The three circuits above will have the same gain but when they are connected to a following stage, circuit **A** will deliver more signal-amplitude and the amplitude of circuit **C** may drop to almost zero because the input impedance of the following stage will be so low that the energy from the 47k will produce a very small waveform under "loaded conditions."
Now you know what causes the problem.



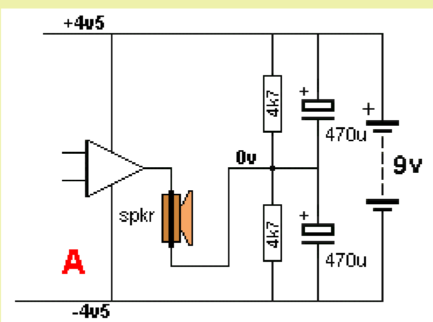
There are basically two ways to bias a transistor. Circuit **A** is called **SELF-BIAS** and circuit **B** is a **BRIDGE**.
We are assuming all resistors are correct to get half-rail voltage on the collector.
Circuit **A** will maintain mid-rail-voltage over a wide range of supply voltages without having to change any of the resistor values. Changing the transistor for one with a different gain will alter the collector voltage by a small amount. It is a very reliable and stable circuit.
The only problem is the gain of the stage. It is about 70 for all types of transistors because the gain is reduced by the feedback effect of the base-bias resistor.
The collector voltage for circuit **B** will change considerably when the supply voltage is changed and if the transistor is changed for one with a different gain.

If an electrolytic is connected across the emitter resistor, the gain of the stage can be as high as 100 but it is best to keep each stage below 100 and use more stages. This will prevent circuit-instability such as "motor-boating" and "squealing."

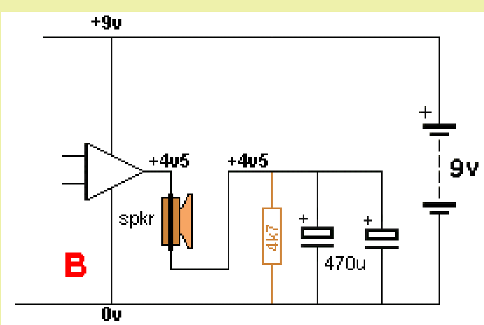
DESIGN VALUES

This is one of the most important topics when designing a circuit. It has never been mentioned before in any text book.
When designing a circuit, each value of resistance and capacitance has a "correct value." In other words, what me mean is this: When a "qualified" electronics engineer sees a circuit, he expects to see a certain value of resistance or capacitance for every component and when this value matches his understanding, he understands the circuit is operating exactly as expected. If the value is 50% higher or lower, it can still be within the expected range, but when the value is 10%, he will look into the reason for the variation.
Most circuits can tolerate a wide range of values, however certain values are chosen to indicate the fact that the value is non-critical.
We call these values "design values" and are the first values you think of when designing a circuit.
If a circuit needs a slight adjustment, these values will be increased or decreased slightly and and when an engineer see this, he understands the values are fairly critical.
That's why you don't use 12k instead of 10k or 560R instead of 470R when the "design values" will work perfectly.
You are simply introducing unnecessary complexities into the circuit and reducing your status as a "design engineer."
We are still seeing engineers creating a circuit with a parts list and when the circuit is displayed on Google, it has no values!
Finally, remember to lay-out a circuit using symbols and not line-diagrams of a chip with pin numbering 1,2,3,4 etc. A schematic has nothing to do with parts-placement and a block diagram of a chip tells you nothing about the function of the chip.

SPLIT POWER SUPPLY



Some circuits need a voltage that is identified as 0v voltage at a particular connection and a positive voltage and a negative voltage.
The reason for this is the output of the circuit has a voltage that is half-way between the voltage on the top rails and the bottom rail and it produces a signal that rises almost as high at the top rail and almost as low as the bottom rail.
This means the amplifying circuit, such as an op-amp or AMPLIFIER, requires a voltage that is equally POSITIVE and NEGATIVE, with the earth, or chassis or neutral classified as having zero voltage. In other words it is the reference point (0v) for all the other voltages.

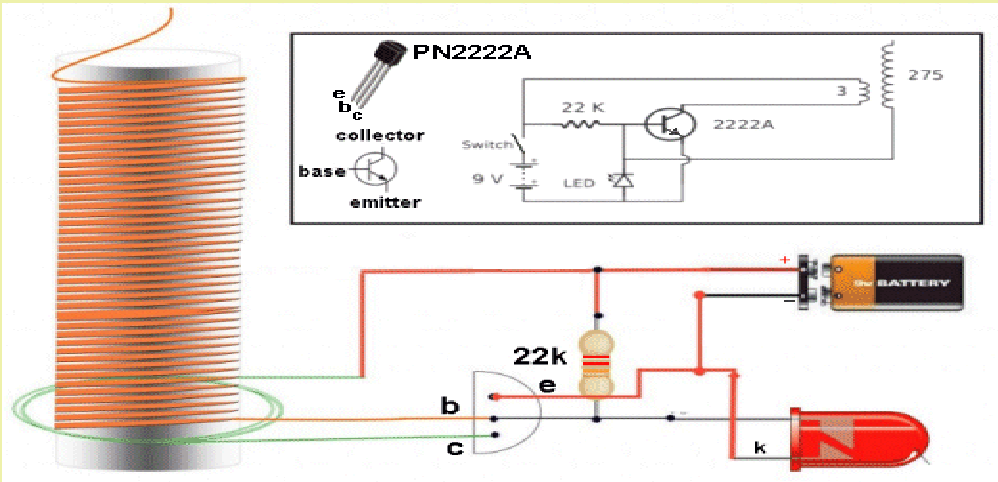


As far as the output is concerned, the two 470u electrolytics are connected in PARALLEL and prevent the bottom lead of the speaker moving, when a signal is delivered to the top lead.
The do not prevent the bottom lead moving like a fixed connection but limit the movement or restrict the movement just like a 2 ohm resistor.
A 100Hz, the two 470u electrolytics have a resistance (impedance) of slightly less than 2 ohms and at a higher frequency this value is a lot less. That means most of the signal will appear across the speaker.
In How A Capacitor Works we explain how you "see" the electrolytics working.

INDUCTION

Here's a new term.
It is **INDUCTION** and it means a circuit or transistor is turned ON or OFF by a voltage produced by a field. It

means there is no direct wiring between the two circuits and and they are linked by a magnetic field or flux.
This is sometimes called TRANSFORMER ACTION.
The field from one winding **INDUCES** a field near another winding and this field produces a voltage and current to operate or drive of affect the other circuit.
This effect is identified by the fact that the two windings **DO NOT TOUCH**. The only thing that couples them is the magnetic flux.



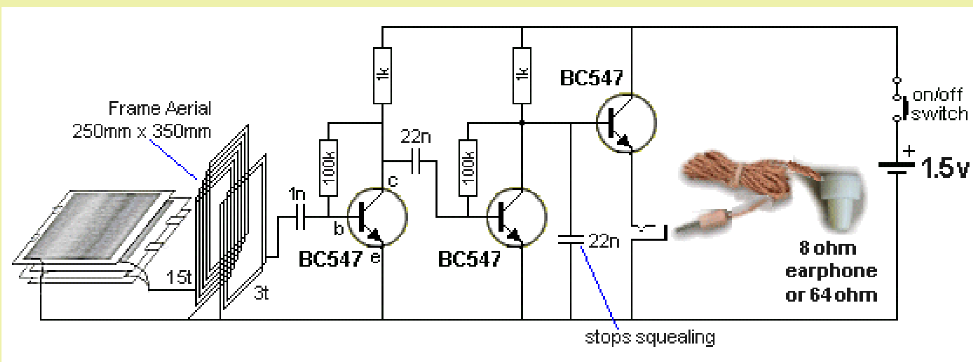
In the circuit above the transistor oscillates and produces a very high voltage at the the top of the coil.
The centre of the coil is a magnetic material such as ferrite. This is important
as it delivers the flux produced by the 3-turn winding to the 275 turns of the transformer.
Removing the ferrite core will leave air to do the transfer and air is not as good as ferrite as transferring the magnetic flux. Ferrite is up to 1,000 times better.
The circuit is turned on a little bit by the 22k on the base and this produces a small amount of flux in the 3 turns.
This flux cuts the 275 turns and produces a voltage. Because the 275 is only connected at one end, we have to explain how it works.
The voltage produced by the 275 turns comes out both ends of the winding and it will be a negative voltage out one end and a positive voltage out the other end.
The winding is connected so the positive voltage comes out the bottom and even though the top of the winding is not connected to anything, the voltage out the bottom will deliver a small current to the base of the transistor and turn it ON more.
This increases the magnetic flux and the transistor turns on until it is fully turned ON.
Up to this point in time the magnetic flux is called EXPANDING FLUX and it is capable of cutting the 275 turns. But when the transistor is fully turned ON, the flux is a maximum but it is not expanding. It stops EXPANDING. It is STATIONARY FLUX and the voltage produced in the 275 turns immediately STOPS.
The transistor turns OFF immediately because the voltage (and current from the 275 turns stops being delivered to the base) and the flux in the magnetic core collapses. It collapses because the current delivered by the transistor STOPS.
The collapsing of the magnetic flux produces a voltage in the 275 IN THE OPPOSITE DIRECTION and the voltage out of the bottom of the winding is NEGATIVE. This turns the transistor off fully and a very high voltage is produced in the winding because the magnetic flux collapses very quickly.
This is the spark or CORONA or HIGH VOLTAGE produced by the "Tesla Coil."
When the magnetic flux has full collapsed (and converted to a very high voltage), the voltage ou of the bottom of the 275 turns is zero and the transistor gets turned on a small amount by the 22k to start the next cycle.
Because the 275 turns is only connected at one end, the energy into the base can only be very small because the winding does not have at connection at the top to act as a "fixed point" to deliver a high current.
It's like trying to push a car while standing on a skateboard. The voltage has a "little bit of grip" as it expands and this is just enough to get the circuit to work.
In actual fact, the voltage out to bottom of the winding is just as high as the top spark, but the base of the transistor converts this energy to a small voltage and small current to turn the transistor ON.
This gives the winding a "fixed point" to produce a spark at the top.
The high voltage is INDUCED or PRODUCED in the 275 turns when magnetic flux in the core collapses very quickly.

DECOUPLING

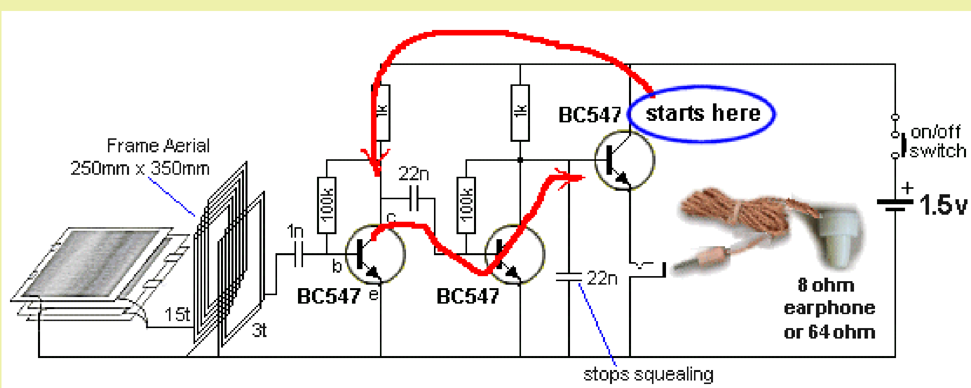
Decoupling is done with capacitors. To understand how a capacitor works, read this article:

HOW A CAPACITOR WORKS It has animations to show a capacitor charging.

Decoupling is soldering capacitors or electrolytics to a circuit to prevent signals from one stage entering another and creating a problem. And there are other explanations too. There are quite a number of words and terms that are used for capacitors in a certain location in a circuit.
The problem might be squealing, motor-boating or causing a stage or an output to pulse or operate at the wrong time. Or another 10 problems. We will only cover a few.
The capacitor (electrolytic) absorbs the unwanted signal (by charging and discharging) and this is how it is removed. You can also say the capacitor prevents the voltage rising or falling because the voltage is actually a very narrow pulse of high amplitude.
The capacitor converts this waveform into a low voltage - by simply absorbing the energy contained in the waveform. What the capacitor is actually doing is absorbing the energy and releasing it during another part of the cycle.
Whenever a device such as a relay or speaker is activated, it takes additional current and the voltage of the supply drops a small amount.
This "dip" is transferred to the previous stages (or other stages) and these stages can be sensitive to very small changes in voltage.
In the circuit below, the first stage thinks the noise is due to the signal from the radio station and it gets amplified along with the real signal the station.
The signal eventually appears in the speaker and is then transferred to the supply rail as a "glitch" or "spike" where it is again passed to the "front-end."
Very soon the signal is amplified sufficiently to produce a squeal or "putt-putt-putt" noise called "motor-boating."
Audio amplifiers and radios are particularly difficult to design because you need an enormous amount of amplification and this allows feedback in the form of squealing to be produced.
The following circuit has this problem and the cure was to add a 22n to the output stage to prevent the high frequency signals being amplified and cycled through the circuit.

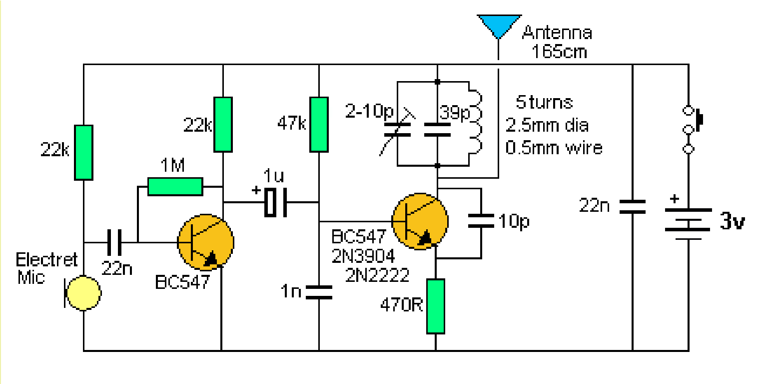


The layers of aluminium foil between cardboard form a tuning capacitor to select the stations.

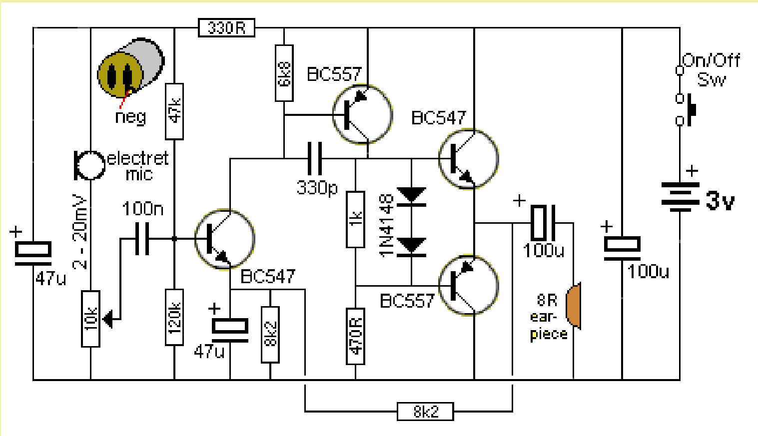


The unwanted signal starts at the output because a loud signal takes more current and this causes the supply voltage to drop. It puts a pulse on the top rail.
This pulse is passed to the first transistor where it is amplified about 50 times.
The second transistor amplifies it another 50 times and it cycles around the circuit again and again and again - each time getting louder and louder.
The 22n absorbs the signal and prevents most of the squeal.
This is an unusual form of decoupling and it is classified as DECOUPLING because the intention of the 22n is not to alter the audio but remove the squeal.

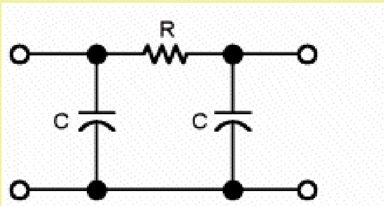
BATTERY DECOUPLING simply means the decoupling component(s) are near the battery.
In the following circuit the 22n is across the wires that come from the battery.



The circuit above is called a high frequency circuit (90MHz) and the wires and leads and tracks on a printed circuit board from the battery to the circuit are 100 times more critical than an audio circuit.
Let me explain why.
The coil in the diagram is wound with wire but it can be created by using a zig-zag type track on the PC board or a circular track like a snail-shell. It only has to be 5 turns and if one end is held stationary, the other end will have a signal equal to about 6v on it.
This shows what can happen with a short length of track.
Where the coil meets the top rail in the circuit above, the join is trying to move up and down at 90MHz and if the track between this junction and the battery is long and thin, it will become part of the coil and start to move.
Two things will happen. It will change the frequency of the circuit and, because it does not have a 39p capacitor across it, the energy delivered to it will be lost.
The 22n effectively tightens up the power rails and prevents them moving.
We also say the 22n reduces the **impedance of the rails**.

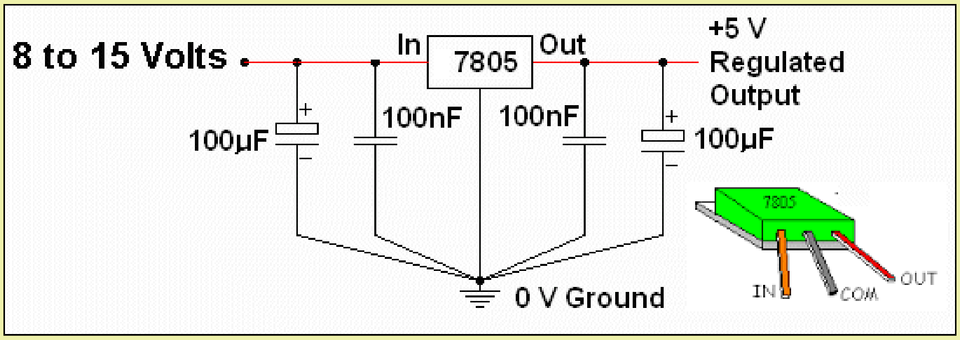


Decoupling is improved enormously by adding a resistor in series with the capacitor (electrolytic).
In the hearing-aid circuit above, the second 100u across the battery is designed to improve the performance of the battery when it is getting weak and at the end of its life.
The 100u is providing the pulses of high current when the battery is weak. It also reduces the amplitude of the pulses on the power-rail, as these pulses will be sent back to the front-end and cause motor-boating.
This type of amplifier has a very high gain and even the smallest signal from the output will cause instability.
To reduce this a second decoupling arrangement is provided for the microphone and first transistor.
It consists of a 47u and 330R resistor.
The resistor increases the effectiveness of the 47u by about 100 times.
It works like this: The resistor and capacitor in series is called a TIME-DELAY circuit. When a peak or pulse appears at the right-hand lead of the 330R, it passes through the resistor INSTANTLY and begins to charge the 47u. Suppose the pulse is 10mV. After one-hundredth of a second the voltage on the capacitor will be 3mV.
This means 100Hz signals will be reduced to 30% and any higher frequencies will be reduced to 10% or less.
When the current is very small, as in this case, the effect of the two components is to reduce the signals that create a squeal by as much as 99%. They are highly effective. The squeal is completely eliminated.



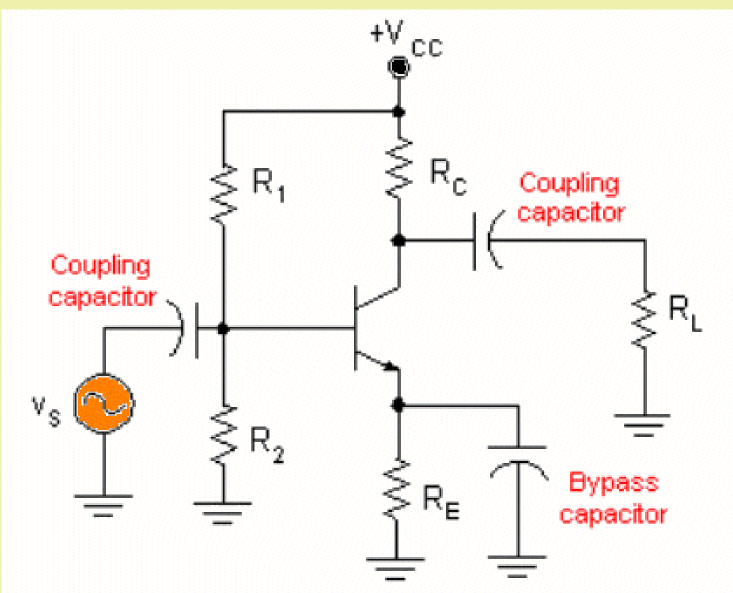
The two capacitors (electrolytics) and resistor form a pi filter. This type of circuit is called a **low-pass filter**, but we are using it to remove high frequencies and we are considering it as a "high-frequency eliminator."
The 330R and 47u are enormously effective in doing this as the calculation for the 330R and 47u show that signals above 10Hz are reduced or eliminated completely. Feedback squeals are 3kHz and above. These signals are completely eliminated.

DECOUPLING A 7805 REGULATOR

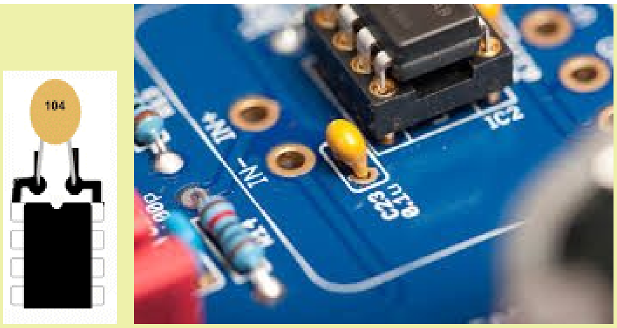


This circuit shows two things.
The 100n on the input and output have nothing to do with filtering or smoothing the voltage.
They are designed to prevent high-frequency oscillations (approx 1MHz) being generated by the 3-terminal regulator.
The regulator is actually a high-gain amplifier and it will produce oscillations if the 100n capacitors are not fitted.
Secondly, the diagram shows that the capacitors should be placed very close to the common lead of the regulator by showing the leads going diagonally to the 0v point. This must be done so they have the greatest effect on eliminating the self-oscillation.
These capacitors are called **DECOUPLING CAPACITORS** because, in electronic terminology, when you isolate a component from a source of interference, it is called decoupling.
Even though the 100u is a much-higher value, it has almost no effect on reducing the self-oscillation.
We mentioned above, the effect of a PC board track on 90MHz frequency.
If the distance between the waveform and the capacitor is long, a signal will be generated by the track.
This time the track is inside the electrolytic. The electrolytic is made up of a spiral layer of foil and a high-frequency signal on the positive lead will not be reduced.
Tantalum capacitors are constructed differently to aluminium capacitors and WILL have an effect on reducing the oscillations.

Another form of Decoupling is BYPASSING. In the following circuit the capacitor is allowing the signal to bypass the emitter resistor and it does this by effectively making the top of the electrolytic equal to the 0v rail. It is does this because the electrolytic takes time to charge and discharge and the emitter thinks it is connected to the 0v rail. It holds the emitter lead tight and prevents it rising and falling.



The Bypass Capacitor is called and **EMITTER BYPASS CAPACITOR**



100n BYPASS CAPACITOR

The 100n capacitor connected to the positive and 0v pins of the chip is called a BYPASS CAPACITOR.
It prevents noise on the power rail getting into the chip it is protecting.

Some projects may have 2, 10 or 50 capacitors that are designed to prevent the rails "moving" and prevent spikes and glitches passing from one section to another.
These capacitors are all part of **"DECOUPLING"** and it is a very complex area to discuss as we are talking about very small, high-speed, signals that can create an enormous number of faults.

CIRCUIT PROBLEMS:

CIRCUIT 1

The input to a microcontroller needs a HIGH when a microphone picks up audio. This is the requirement from a customer. The circuit in **Fig 104** was designed to meet the customers requirements. The 10mV audio waveform from a microphone is converted to a 4v-5v CONSTANT HIGH. The following circuit is the result:

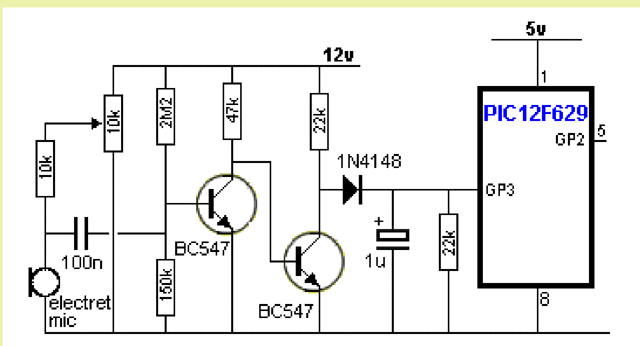


Fig 104.

The starting point is to bias the first transistor so the voltage on the base is just at the point of turning it ON. This allows the 47k resistor to turn on the second transistor and the diode does not see any voltage. This means the 1u does not get charged and the input to the microcontroller sees a LOW.
This is called the QUIESCENT (standing, stand-by or idle) condition.
The gain of the electret microphone is adjusted by the 10k pot and when it receives a loud audio signal it produces an output of about 20mV.
This signal is sufficient to turn ON the first transistor and turn OFF the second transistor so that signal diode sees a HIGH pulse via the 4k7.
This voltage is passed to the 1u and it gradually gets charged. When the voltage on the 1u reaches about 4-5v, the microcontroller sees a HIGH and the program in the micro produces an output.

CIRCUIT 2

How does this amplifier get biased?:

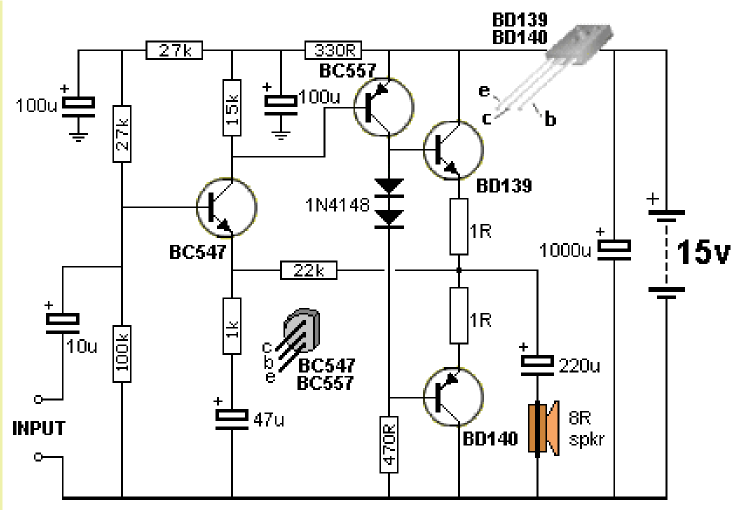


Fig 105.

One of the most difficult amplifiers to design and service is a DC (Directly-Coupled) amplifier. The voltage on the output is fed back to the input to create the idle (quiescent) state and the biasing of the input is created from the output. So, where do you start?
All the facts we have learnt in this discussion are needed to understand how this circuit works.
The circuit has high gain and without the 22k feedback, we would not be able to create an output "set-point." The first transistor has no DC voltage gain as but it does have an AC voltage gain of about 22. The BC557 provides a voltage gain of about 70-100 and the output transistors only provide a current gain. This gives the circuit a voltage gain of about 2,000. A 50mV input will produce an output of about 10v.
The aim is to get the output voltage near to mid-rail so it can swing both positive and negative and create a relatively distortion-less waveform.
The starting point is the voltage divider made up of the 27k + 27k and 100k. This puts 10v on the base of the first transistor.
Now we come to the 470R resistor on the base of the BD140 transistor. This resistor is a very low value and is keeping the BD140 turned ON and the emitter voltage will be very small.
Here's the interesting part: The collector of the BC557 can pull the base of the BD140 UP without any difficulty to about 1.4v less than the positive rail, due to the two 1N4148 diodes.

The Two Biasing Diodes
These two diodes prevent both output transistors turning ON at the same time. If the transistors are both turned ON at any point in the cycle, a very high current will flow and create a short-circuit.
How do the diodes work?
Let's remove the diodes and see what happens.
The

and also due to the base-emitter voltage-drops across the two output transistors. But this only raises the collector **about 1.4v**.
To be able to pull higher, the transistor must turn on harder and since the bottom transistor is being pulled down by 470R, the top transistor is also being pulled down via the two 1R resistors. The BC557 sees the base of the BD139 as a 470R resistor, plus the actual 470R resistor. This make it 220R.
To raise the voltage on the base of the BD140, requires current through the 470R and the BC557 needs to be turned on a certain amount to provide current through the 470R and into the base of the BD139 AT THE SAME TIME.
At the moment the join of the two one-ohm resistors has a very low voltage on it and the BC547 is also an emitter-follower and the emitter is about 10v minus 0.7v.
This puts a current through the 22k resistor of less than 1mA however this current also flows through the emitter-base junction of the BC557 and if the transistor has a gain of 100, the emitter-collector current can be as high as 100mA.
However the 220R (470R and 470R in parallel) resistor only needs a flow of 22mA to create a voltage of 5v across it, so we have plenty of gain to begin to turn on the circuit.
The BC557 creates a current-flow through the 470R and the BD140 starts to get pulled UP. This puts less current though the BC547 and less current through the base of the BC557, so the BC557 starts to turn off.
The actual settling-point has a lot to do with the 27k + 27k and 100k base-bias resistors as this puts 10v on the base and the emitter 9.3v. Suppose the output settles at 7.5v. This puts 1.8v across the 22k and creates a current-flow through this resistor. Approximately the same current flows through the emitter-base of the BC557 and about 100 times this current is available to be divided between the 470R and base of the BD139. This is how the output becomes biased at very nearly half-rail voltage.

CIRCUIT 3
Select the best circuit between Figs 106 and 107:

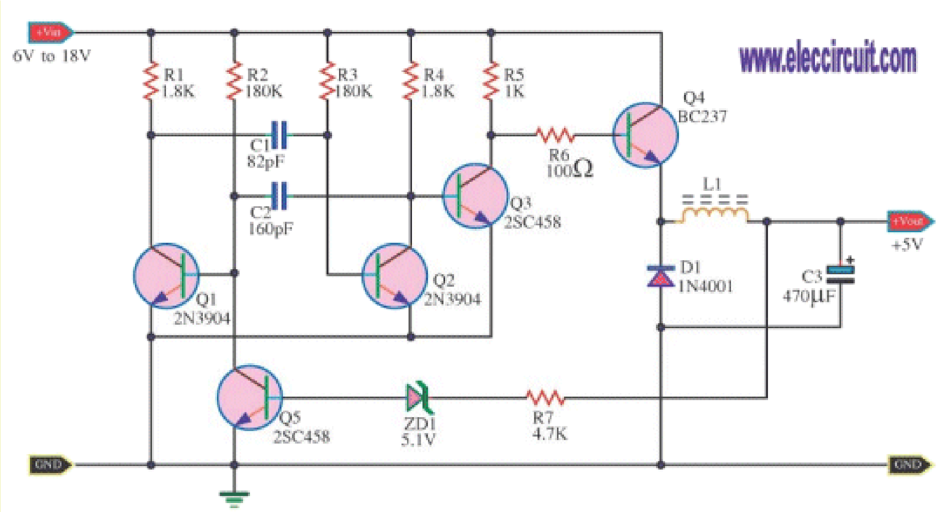


Fig 106.

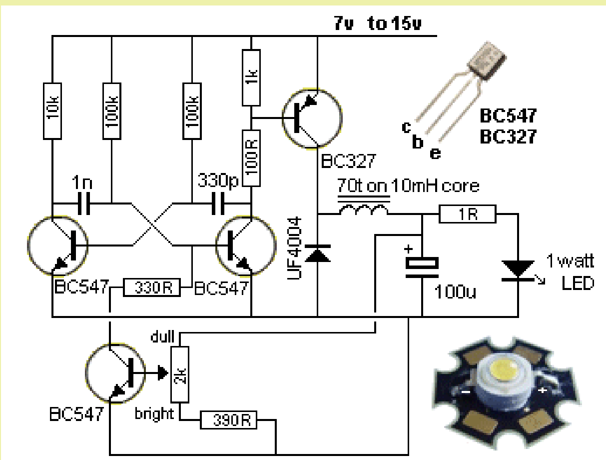


Fig 107.

From the theory discussed above, can you see the problem with driving the BC237 in **Fig106**.
It is being pulled HIGH via the 1k resistor. If the transistor has a gain of 100, Q4 will effectively be equal to a 10 ohm resistor. For 100mA current delivered to the output, 1v will be dropped across this transistor and it will start to get hot. This is wasted energy.
A BC237is only capable of delivering 100mA.

Fig 106 has been re-drawn as **Fig 107** with improvements and corrections.
The output transistor has been changed to a BC327. It will handle 800mA.
A 1N4001 is not a high-speed diode and using an Ultra Fast 4004 will deliver an extra 50mA to the output.
See: 200 Transistor Circuits for details.

CIRCUIT 4

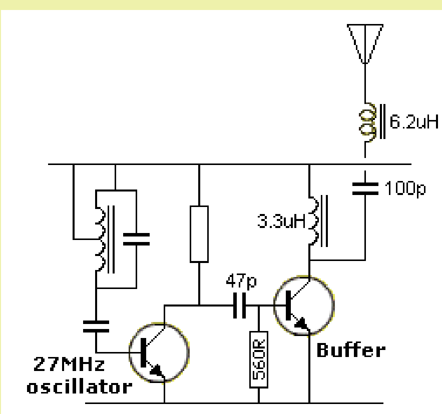


Fig 107a.

Fig107a shows a 560R resistor to discharge the 47p coupling-capacitor.
The circuit is a 27MHz transmitter with buffer. The buffer is an amplifying stage to increase the output.
You will notice two things: the buffer stage is not biased ON and a low value resistor is connected between base and 0v rail. This called a "Class-C" stage.
This resistor discharges the capacitor so it will transfer the maximum amount of energy (on each cycle), from the oscillator stage to the output stage.
The resistor is not needed when charging the capacitor but it is very important to discharge the capacitor.
Remove the resistor and the output will be nearly ZERO!

Another point to note with a **"Class-C" stage** is this:
All the energy to turn-on the Buffer stage comes from the coupling capacitor.

CIRCUIT 5

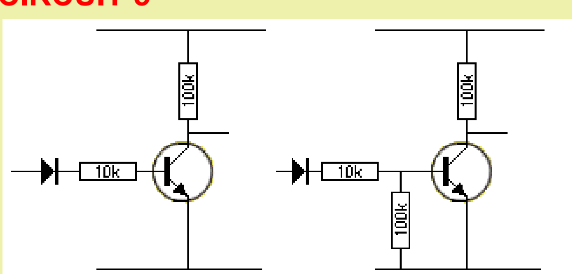


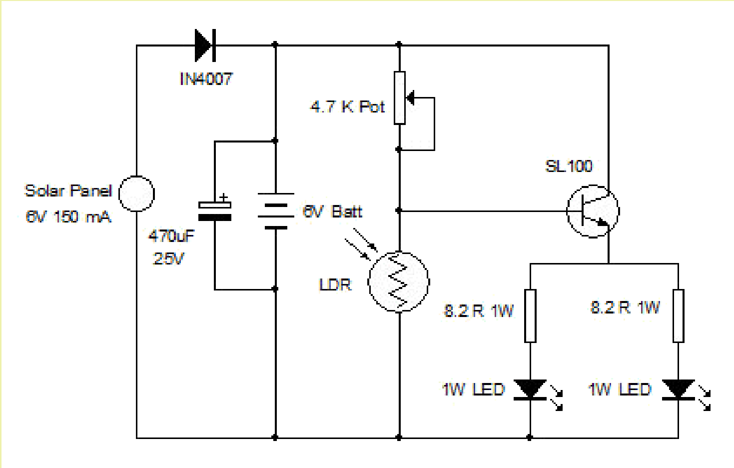
Fig107b shows a transistor that is turned on via a diode on the base.
This is a BAD design. The transistor is said to be in a HIGH IMPEDANCE STATE, when not turned ON.
This means the base is FLOATING when the anode end of the diode is at 0v.
When the anode of the diode is LOW, it does not deliver any voltage to the base and the effective resistance on the base is infinite and any noise picked up by the base will turn the

Fig 107b.

The high-value collector load also gives the transistor in the first circuit a high possibility to pick up noise on the base and produce pulses on the collector.

transistor ON. To prevent this from happening, a 100k resistor is connected between base and 0v rail.

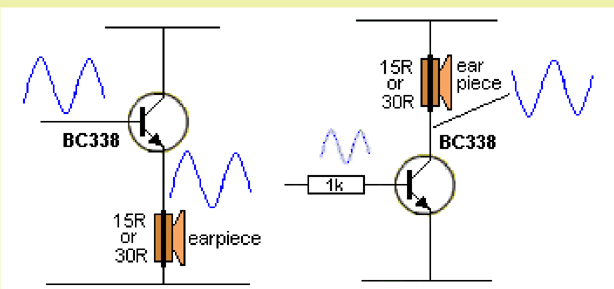
CIRCUIT 6



Solar Night Light

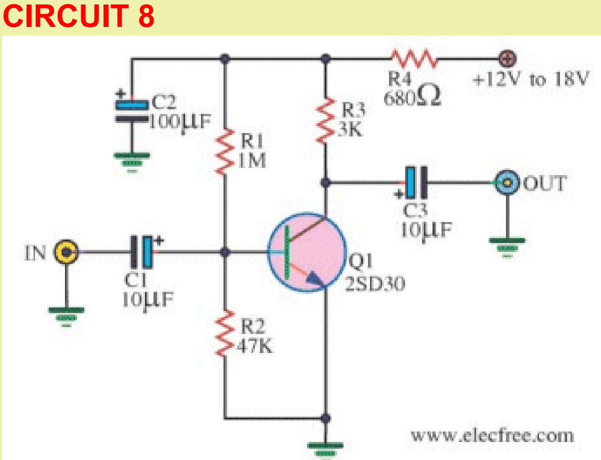
Here is a poorly-designed circuit.
A 1 watt white LED has a characteristic voltage of 3.2v to 3.6v and it takes 300mA. The voltage drop across 8R3 will be V=IR =.3 x 8.2 = 2.46v The base voltage will be 3.2 + 2.46 + 0.7 = 6.36v
The LEDs will not turn on very brightly. A white LED will start to turn on at a lower voltage but the full brightness is not achieved until 300mA is flowing and this will produce a voltage of about 3.2 to 3.6v across the LED.
There is another major fault with the circuit.
The transistor is only designed to pass 500mA. It is over-stressed. The base current will be about 20mA to 40mA. This current must be supplied by the 4k7 pot.
This current is too much for a pot.
Secondly, the current must flow through the LDR when it receives illumination, so that the current is removed from the base of the transistor. This current is too high for the LDR.
You can learn a lot from other designer's mistakes.

CIRCUIT 7



Anil wanted to increase the volume from his mobile handset using a single transistor and a few components.
He has a choice of using an emitter-follower or common-emitter amplifier, as shown in the two circuits.
The first circuit will only increase the current.
The second circuit will increase the current AND the voltage of the waveform and is the best circuit to use.

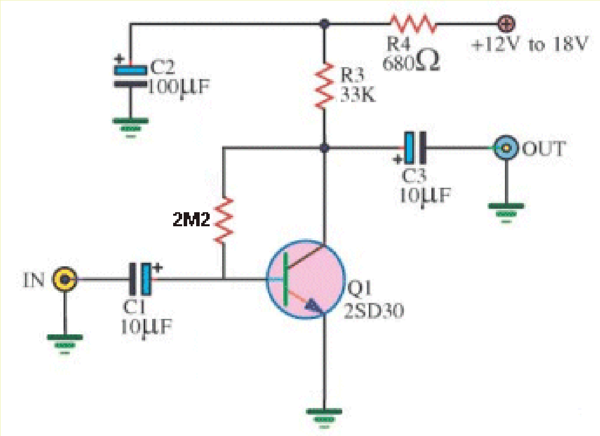
CIRCUIT 8



This circuit is a "semi-bridge-configuration.
But it does not have an emitter resistor. The emitter resistor allows the stage to self-adjust the current through the collector-emitter of the transistor to produce an approximate mid-rail voltage on the collector.
Without this resistor it is very difficult to produce mid-rail voltage when the supply rail can vary from 12v to 18v and the gain of the transistor can be anything from 100 to 300.

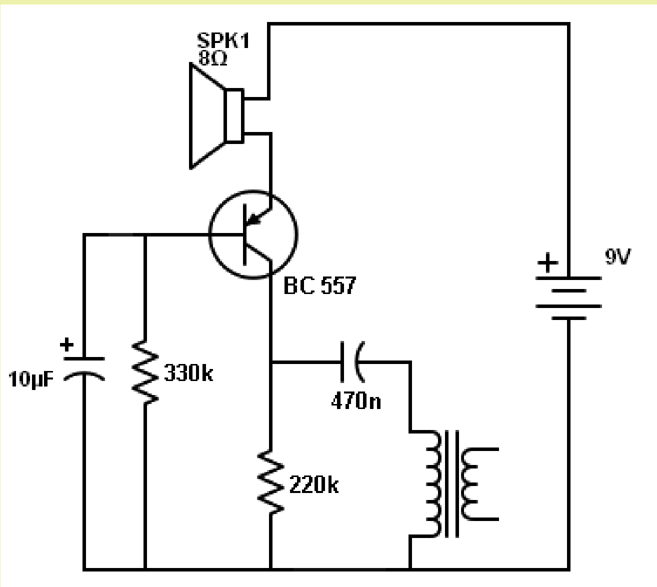
The solution is to change the biasing to SELF BIAS.
This involves a resistor from collector to emitter. The stage will now have a voltage on the collector and by testing a number of transistors, you can determine the correct value for the base resistor.

There is one other fault with the circuit. The load



resistor (3k) is too low.
The circuit is a pre-amplifier and if the collector resistor is increased to 33k, the output signal will be increased 10 times.
It works like this: The incoming signal supplies a small current and this is amplified by the transistor (about 100 times) to produce a current in the collector-emitter circuit. This current flows through the collector-load-resistor and produces a voltage across it. If the resistor is a high value, the voltage produced is high and thus the waveform is high and thus the stage produces a HIGH GAIN.

CIRCUIT 9



This circuit is unusual in appearance but it does NOT work.
The transistor is in a COMMON-BASE configuration and we have seen this using an NPN transistor.
You need to turn everything up-side-down to work with a PNP transistor.
The problem lies in the value of the 220k resistor. The value is TOO HIGH.
If the transistor has a gain of 330, it will convert the 330k to 1k and become a 1k resistor.
1k in series with 220k means very little voltage will be dropped across the 1k and the collector voltage will be about 9v.
This means the 470n will be fully charged.
Suppose the transistor turns OFF fully.
The 470n is discharged via the 220k.
When the transistor turns ON, it can only charge the 470n with the energy that has been removed by the 220k.

This means that although the transistor can theoretically act as a 1k resistor, in reality it is only as good as a 220k and it will deliver very little energy to the 470n.
The 220k resistor needs to be reduced to 1k to deliver the maximum energy to the 470n.
The transistor can only CHARGE the 470n. The collector resistor DISCHARGES the 470n.

CIRCUIT 10

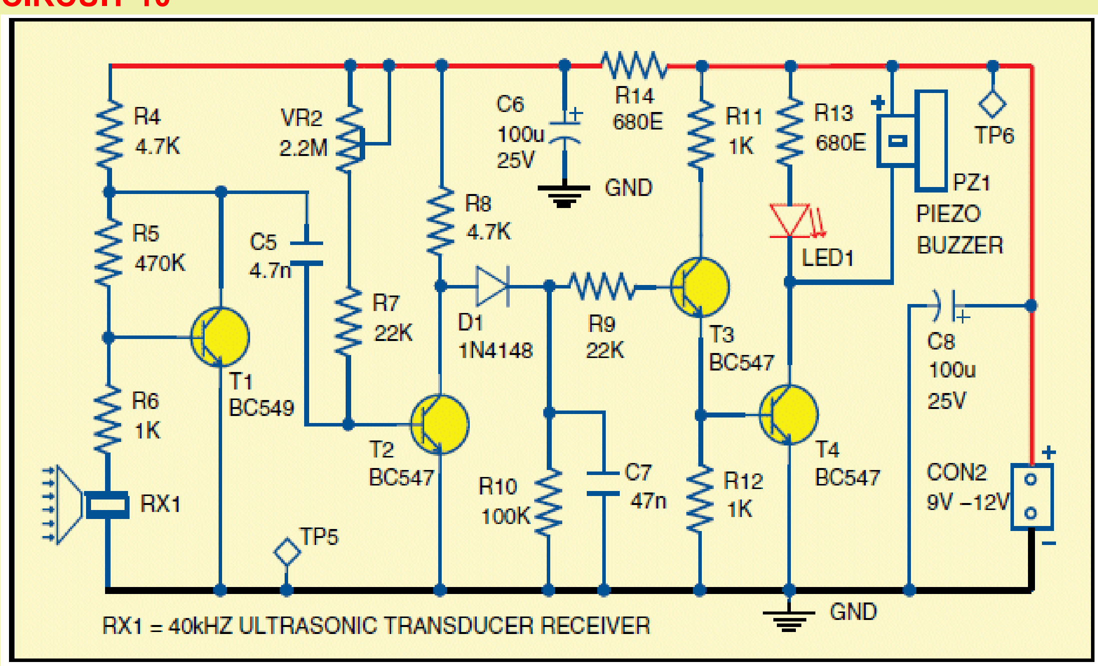
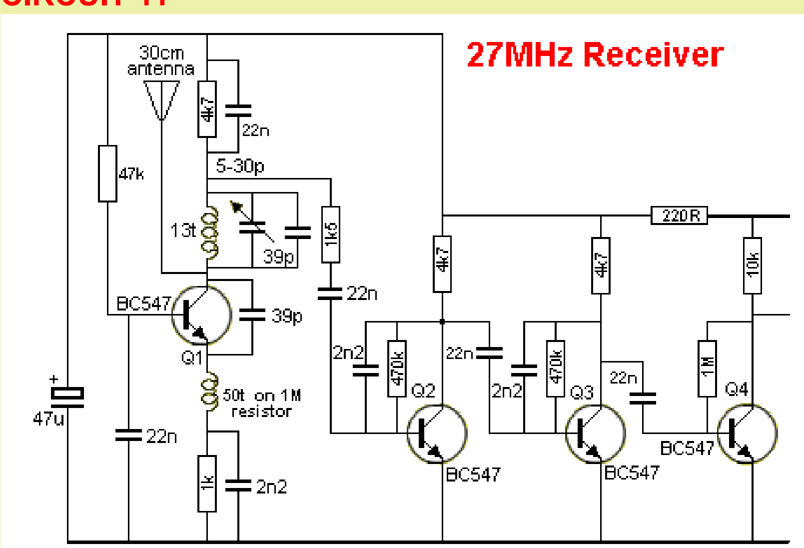


Fig. 2: Circuit diagram of the receiver

This circuit above is poorly designed and has a number of fundamental faults.
You can learn a lot from other peoples mistakes and this is a good example.
NEVER try to control the bias on a stage via the base resistor. This applies when the resistor is connected between base and positive rail. See more on this type of biasing HERE.
This resistor operates entirely differently to a resistor between collector and base.
A resistor between collector and base operates as a NEGATIVE FEEDBACK resistor and adjusts the voltage on the collector to about mid-voltage when the correct load resistor is used and the appropriate base resistor is selected. When this resistor is changed, the voltage on the collector changes a SMALL AMOUNT.
But when the resistor in the circuit above is altered, the collector voltage changes a VERY LARGE AMOUNT.
The arrangement above is NOT a self-biased stage and getting the transistor to a point where it will produce the highest gain is a very difficult thing to do.
The highest gain is when the voltage on the collector is mid-rail, but we need the transistor to have a collector voltage below 1.8v so the final stage is not tuned ON. The voltage cannot be mid-rail.
This means we need to deliver extra current into the base to turn the transistor ON more so the collector voltage is reduced.
This means, to activate this stage, we need to deliver more energy from the 4n7 in the form of a negative pulse, to turn it OFF and allow the 4k7 to deliver current to the stages that follow.
This means the first transistor has to turn OFF more so the 4n7 can charge to a higher voltage so that when the first transistor turn ON, the higher energy will be delivered to the base of the second transistor to turn it OFF. (In other words, the energy from the 4n7 reduces or removes the current delivered by the 2M2 resistor.)
Having the 2M2 as a manual adjustment will decrease the gain of the two stages considerably.
If you turn the transistor ON too hard, the circuit will require a lot of energy from the 4n7 to remove this turn-on current to turn the transistor OFF.
This is the first major fault.
The next point to note is the sensitivity of the diode pump has been reduced by the inclusion of the third transistor. This transistor is an emitter-follower and does NOT assist in the operation of the circuit. In fact it reduces the sensitivity of the circuit. It adds an extra 0.6v to the requirement of the diode pump.
The diode pump is perfectly capable of turning ON the output transistor without the need for the current-amplification of the third transistor.
The output transistor only requires a very small current into the base to operate the piezo sounder (less than 0.5mA) and the 4k7 will deliver this current.
With the third transistor removed, the output transistor is turned ON via the 4k7 on the collector of the second transistor.
The 1k on the base of the output transistor is far too low for a transistor delivering 50mA collector current and should be 10k to 47k.If we do this, we have already increased the gain of the circuit by 10 times to 47 times.
If the second transistor is AC coupled, ALL of the signal from the 40kHz transducer will be passed to the diode pump.
If the signal on this transistor is 1,500mV, the output will respond if the third transistor is removed.
This requires 30mV into the base of the second transistor.
To get 30mV on the collector of the first transistor the transducer needs to produce less than 1mV. This will be the maximum sensitivity for the circuit and it is AUTOMATICALLY self-adjusting and AUTOMATICALLY delivering the maximum overall gain without any need for adjustment.
This is how to work out the requirements of the circuit.
It is a **VOLTAGE REQUIRING** circuit not a **CURRENT REQUIRING** circuit.

CIRCUIT 11



Here is a description of the circuit above, including an understanding of how the two "coils" work in the first stage:

THE "FRONT-END"

The secret to getting a long-range 27MHz link is a powerful transmitter and a sensitive "front-end" on the receiver.

A 27MHz transmitter of only a few milliwatts (10 to 30 mW) will reach 100 metres providing the receiver has a very sensitive FRONT END.
The Front End is the first stage of a receiver.
In our case it is a very weak 27MHz oscillator and thus it is actually a 27MHz transmitter (or more accurately - a 27MHz radiator) as it fills the surroundings with a 27MHz signal.
When another 27MHz signal enters this field it upsets the transmission of the receiver and increases the amplitude of the oscillator. This has the effect of producing a cleaner signal and the background noise or "hash" is reduced.
This is a very clever way of making the front-end very sensitive as it takes a lot of energy to "excite" an oscillator that is sitting in a dormant condition. It is also very difficult to get an oscillator to sit in a condition that is just before the point of oscillation. So we cause it to oscillate at a very low level and an incoming signal will increase the amplitude.
The fact that the transistor in the front end is oscillating can also be referred to as a REGENERATION circuit as the output of the transistor - at the collector - is fed back into the circuit via the 39p between the collector and emitter.
The signal delivered by the 39p is prevented from being lost to the 0v rail by the 50 turn inductor. This is called "emitter injection" as the transistor is configured as a common base amplifier in which the base is held firm by the 22n and the signal fed into it via the emitter.
The operation of the circuit is kept at a low amplitude and when the antenna picks up a signal of exactly the same frequency, the amplitude increases. This is called SUPER REGENERATION or increase of the regeneration.
It is a very simple way of getting an enormous result from very few components. Normally you would require 2 or more stages of amplification to produce the same result.
The only problem with a SUPER REGENERATIVE circuit is the background noise it produces. But since this project is designed only to activate a load, this background "hash" is not a problem. Nearly all the background noise is removed by the feedback capacitors on each stage.
A capacitor placed between the collector and base of a transistor has an enormous effect on reducing the high frequencies.
That's why a small capacitor such as 2n2 can be used. The gain of the transistor (about 70) multiplies the effective resistance (impedance) of the capacitor by about 70 and the background noise is removed because it mostly consists of high frequencies.
But there is still a lot of skill to get the front-end to oscillate very lightly, while being sensitive to signals coming from the antenna.
A high-value resistor in the collector only allows a small current to flow and if the supply voltage is high, this produces a circuit that will oscillate with a small waveform and can be easily "upset" or "modified" by an injection at the highest point of oscillation. If this injection is timed accurately, it will increase the amplitude of oscillation and the high voltage supply will allow this to occur.

The output of the front end is taken from the collector of the transistor - but not directly from the collector as this would load the circuit and stop it oscillating. The top of the oscillator coil will have a small percentage of the waveform (that is generated on the collector) and we can amplify it via three stages of amplification. The important thing is we can only pick off a very small percentage of the energy from the oscillator so the front end keeps oscillating.
The signal appearing at the "pick-off" point consists of:
1. - 27MHz frequency called the "carrier frequency,"
2. - a lot of noise and "hash" produced by the circuit and also from the antenna picking up background noise from the surroundings and
3. - a tone from the transmitter.
The tone is about 1kHz and its frequency is considerably different to a 27MHz frequency so a simple PASS FILTER can be used to remove the 27MHz and only allow the tone and noise to pass to the next stage.
The component that does this is the 22n across the 4k7 in the supply-line.
This capacitor effectively passes (shunts - removes) the 27MHz to the positive rail where it is passed to the 0v rail via the 47u electrolytic. Thus it NEVER gets passed to the amplifying stages.
We only want to VERY LIGHTLY load the front so we don't stop the circuit oscillating.
We do this by using a resistor and capacitor in series.
If we just use a capacitor, the "resistance" of the capacitor will be quite small at some of the frequencies of the "hash" and it will load the circuit and reduce the amplitude when a signal is being received. Even though the top of the oscillator coil is connected to "earth" via a 22n, another 22n "pick-off" will reduce the signal slightly as it will have a "resistance of about 5k to 7k because it is only passing audio frequencies. To increase this resistance we add a resistor in series with the "pick-off" capacitor.
The combination of the resistor and capacitor in series reduces the LOADING effect.
We now have a very small signal that can be amplified by the following 3 stages.
The second transistor amplifies this signal and removes a lot of high frequencies (hash) via the 2n2 feedback capacitor.
The third transistor does exactly the same and we finish up with a signal that is almost equal to rail voltage from the fourth transistor.
We need a very high amplitude signal for the PIC12F629 microcontroller. That's why there are three stages of amplification.
The microcontroller counts the number of cycles in 100mS and determines if the tone is from button A or B. We could have a count in 10mS because the two frequencies differ by 100%, and this is something you can do when you start writing your own programs for a microcontroller.
It also counts in increments of 100mS and if the signal is present for 5 x 100mS, it is counted as a long pulse.

THE INDUCTOR

The inductor on the emitter of the transistors plays a very interesting part in the operation of the circuit.
The transistor is configured as a COMMON BASE amplifier and the base is held rigid by the action of the 22n on the base.
Amazingly, this capacitor has a "resistance" of less than 0.5 ohm at 27MHz and so you can see the base is held firmly.
The signal on the collector is passed to the emitter via a 39p and its "resistance" is about 150 ohms at this frequency. So you can see the signal on the collector has a fairly low resistance path to the emitter and this capacitor will have an effect on the amplitude of the signal on the collector.
However this capacitor does two things. It turns the transistor ON more and it turns the transistor OFF.
Let's see how the capacitive reactance (the resistance at 27MHz) has an effect on the amplitude of the signal.
We know the base is held rigid but the emitter is also held rigid when the signal is not increasing or decreasing.
It is held rigid because the inductor has a very small resistance (3 ohms) and the 2n2 capacitor between the inductor and 0v needs time to charge and discharge and so it also holds the voltage on the emitter at a rigid potential.
But let's look at the effect of the base-emitter junction. When the 39p tries to LOWER the voltage on the emitter, it has the effect of turning the transistor ON more and the base-emitter junction acts like a very low resistance.
This means that when the voltage on the collector is reducing, the 39p acts like a very low resistance to lower the voltage on the emitter and the voltage on the emitter drops by only a few millivolts.
During this time what is the inductor doing?
To answer this we will explain how a capacitor and inductor works.
A capacitor is like smashing up against your opponent in a football match. He wont let you pass him and he grabs on to you so you cannot back away.
That's what the 2n2 capacitor does when it sees an increasing or decreasing voltage. It RESISTS the increase or decrease and the top of the capacitor is just like connecting to the 0v rail.
But an inductor is different.
It's like your team mate lifting you up to reach the ball when you charge at him.
If you supply an increasing voltage to one end of an inductor (the other end is at 0v), the inductor will produce a voltage of the same amplitude and it will seem the INDUCTOR HAS DISAPPEARED !
This is the most important concept you will learn about inductors. Once you realise the inductor disappears, you can see how it has no effect on reducing the signal.
That's exactly what happens in this circuit.
The inductor allows the signal through the 39p to have an effect on controlling the voltage on the emitter without absorbing any of the energy.
The inductor does not have any positive effect on the circuit, is just does not have any loading effect.
In other words, the voltage developed across the inductor does not add to the waveform. But the coil on the collector DOES have an effect on the amplitude of the waveform.

THE TOP INDUCTOR

The top coil (inductor) is actually part of a building block (circuit) called a TANK CIRCUIT.
It just needed a capacitor to be called a tank circuit. The capacitor can be in series or parallel, but it is normally a parallel circuit. This name came from the early days of radio where they realised the coil and capacitor stored energy during the first part of the cycle and released it during the second half. It stored energy like a water tank.
This coil works in a completely different way because it has a capacitor connected across it.
The bottom inductor acts like a HUGE opponent that NEVER lets you through.
The top coil acts like a much smaller opponent that you can reason-with and create a double "high-five." The transistor delivers energy to the coil and it produces a voltage on its lower lead so that the voltage across the coil is equal to about rail voltage.
The transistor now turns off and the magnetic flux created by the coil collapses and produces a voltage in the opposite direction and this voltage charges the capacitor across the coil.
This reverse voltage can be equal to about rail voltage.
This means the amplitude of the positive voltage and the amplitude of the negative voltage can be as high as twice rail voltage and this signal is passed to the antenna. In our case this amplitude is much smaller, but for a transmitter, the amplitude can be 2 x rail voltage.

THE OSCILLATOR

The first transistor is a 27MHz oscillator.
How does it oscillate?
It oscillates because a signal from the output is fed back to the input.
The feedback signal must be POSITIVE FEEDBACK. Negative feedback will not start an oscillator operating and any negative feedback fed to an operating oscillator will reduce the output and may even kill the oscillator.
So we need POSITIVE FEEDBACK. But this is not the complete answer. The feedback signal must deliver slightly more energy than the transistor requires, at each part of the wave. As the transistor turns ON more and more, it requires more energy from the feedback signal to do this. That's why the value of the 39p feedback capacitor is larger than necessary.
Suppose we use a 10p capacitor, the transistor will turn on and feed some of the energy from the collector to the emitter. But as it turns ON more, the base-emitter junction requires additional energy and the 10p cannot provide this. The result is the transistor does not turn ON fully and it stops oscillating. Alternatively, it may oscillate but at a lower amplitude.
The feedback capacitor will turn the transistor ON faster than we require.
We want a 27MHz oscillation.
To get the transistor to turn ON and OFF at the required frequency, we have two components on the collector.
These two components are a coil an capacitor.
When they are connected in parallel, the coil picks up signals (called electromagnetic radiation) from the surroundings and a very small voltage is produced by the turns.

This voltage is passed to the capacitor and it charges.
When it is fully charged, it sends its energy to the coil and this takes a certain period of time because a capacitor cannot charge and discharge instantly. This energy-flow back and forth produces a microscopic amplitude and if a surrounding signal has a frequency that exactly matches the natural frequency of the two components, it will increase the amplitude of the signal and continue this oscillatory effect.
The point to understand is this: The coil and capacitor has a natural frequency at which they operate and if we connect them to a transistor, they will output a waveform that is picked up by the feedback capacitor to turn the transistor ON and OFF at the same frequency.
The coil and capacitor form a circuit called a TUNED CIRCUIT and they determine the frequency at which the circuit operates.
The transistor is simply tuned ON and OFF at exactly the time.
There is just one more interesting part to the circuit.
The top of the coil is fixed to the supply rail via the 22n and when the transistor turns ON, the lower end of the coil becomes slightly negative (slightly less than the voltage on the supply rail).
The transistor keeps turning ON until it is fully turned ON. At this point the feedback capacitor stops providing energy to the emitter and the transistor turns OFF a small amount. This reduces the current through the coil and the magnetic flux changes from expanding flux to collapsing flux.
This has the effect of producing a reverse voltage from the coil and now the end connected to the collector has a voltage HIGHER than rail voltage. This voltage raises the voltage on the emitter and has the effect of turning the transistor OFF.
In other words, the transistor is effectively removed from the circuit and the coil/capacitor combination perform their energy transfer as mentioned above.
The end result is a voltage on the antenna that can be twice rail voltage. In our case the amplitude is kept very low but for a transmitter, this voltage can reach twice rail voltage.

THE AMPLIFYING STAGES

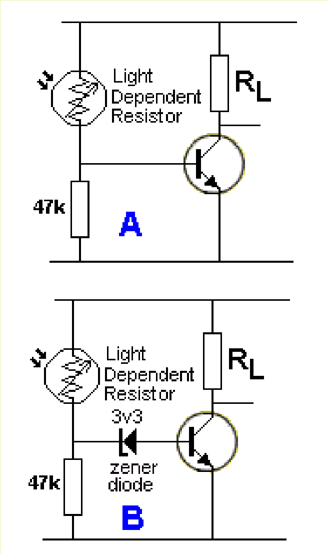
The 3 amplifying stages are called self-biasing common-emitter stages.
The base bias resistor is chosen so the voltage on the collector is about half-rail voltage. This allows both the positive and negative excursions of the waveform to be amplified.
We are not concerned with the quality of the signal (the shape of the wave - the waveform - as we only need to produce a maximum amplitude to feed the microcontroller so it can count the number of pulses - waves - per second.
The value for the components for each stage are chosen by selecting the collector load resistor so the average current will be about 0.5mA. We then select base-bias resistors so the collector voltage sits at about 2.5v.
We then input the signal from the front-end and try capacitors for the negative feedback.
Why waste time working out the values mathematically when it only takes 30 seconds to physically fit a component?
After you generate a mathematical answer, you will want to try different values to see the effect and so it's best to just experiment and see the results on a CRO.
You don't know the gain of the transistor so it's pointless using a mathematical equation to get a result.
The feedback capacitor has an enormous effect on removing waveforms such as "hash" that are higher in frequency than the tone signal, but it also reduces the amplification of each stage. So you have to chose between reducing hash and reducing overall gain of the stage.
Each transistor is called a STAGE.
A stage is a self-contained circuit with a capacitor at the input and and output.
This makes the voltages on the stage entirely generated by the components within the stage because the capacitor on the input and output prevent DC voltages on adjacent stages having any effect.
This makes diagnosis and testing very easy.
If a stage is not working, the first thing you do is check the voltage on the collector of the transistor.
If it is too low or too high, the component may be the wrong value or the transistor may have a very high gain or very low gain. The feedback capacitor may be leaky or damaged or the tracks on the PC board may have a splash of solder.
Audio circuits are very difficult to diagnose and our BENCH AMPLIFIER project can be used to listen to the tone entering and leaving the stage.
You can also use a CRO to view the waveform.
If you want to be really technical you can say the 3 transistors form a "Frequency Selective Strip" - the frequencies being selected are LOW FREQUENCIES.

Another question from a reader:

What is the effect of

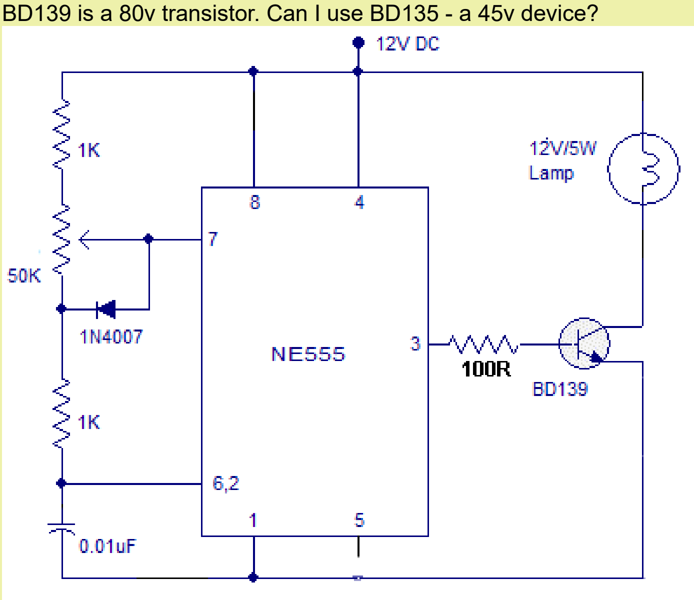
Circuit A turns on when the resistance of the LDR decreases. Nothing happens until the resistance of the LDR reduces to put a voltage of 0.7v on the base of the transistor. At this point the LDR and 47k form a voltage divider and no current flows into the base.
As the resistance of the LDR decreases, current will flow into the base of the transistor and start to turn it ON.
Take note of the level of illumination for this to occur.
If a 3v3 zener is paced in the base-lead, the resistance of the LDR will have to decrease until a voltage of 3v3 plus 0.7v is developed across the 47k resistor. This means more light will need to be detected by the LDR.
As soon as 4v is reached, current will flow through the zener and into the base of the transistor.
Because the change in resistance of the LDR is not linear, the extra amount of illumination is not known, but it will be more than the circuit above.
Once the transistor in both circuits is turned ON, the same amount of current into the base will have the same effect on the LOAD but since the level of brightness on the LDR is different, it may require additional illumination to

adding the 3v3 zener?



produce the same effect in the second circuit.
Instead of fitting the zener, the same effect can be obtained by lowering the value of the 47k resistor.

Question from a reader:
BD139 is a 80v transistor. Can I use BD135 - a 45v device?



The maximum voltage the transistor will see on the collector is about 12volts, so any transistor with a rating above 25v can be used.

There are no inductors (coils or transformers) in the circuit and thus no spikes will be generated.
In many cases, when an inductor, coil or transformer is present in a circuit, a high voltage spike will or may be produced when the current is switched OFF and this can be up to 100 times greater than the supply voltage.
These spikes can damage a transistor and need to be suppressed (prevented) by using a damper diode (a diode connected in reverse across the coil).
If the spikes are say 70v, an 80v transistor can be used.

LAB ELECTRONICS

Lab Electronics produces a "stand-alone" trainer that covers the **common-base**, **common-emitter** and **common-collector** stages:

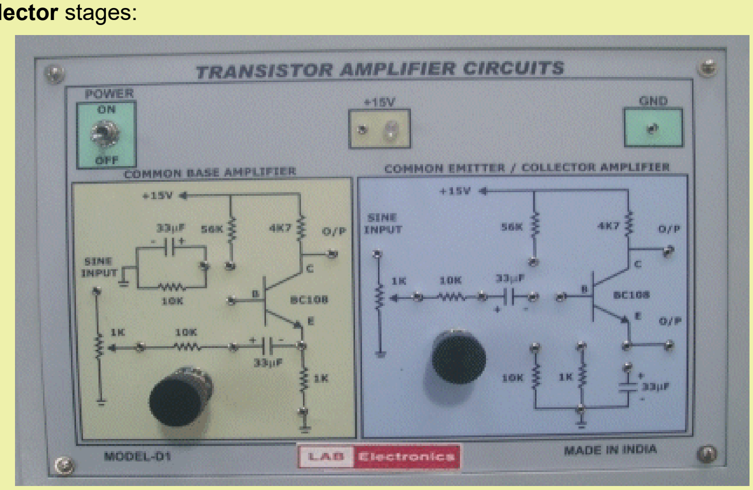


Fig 108.

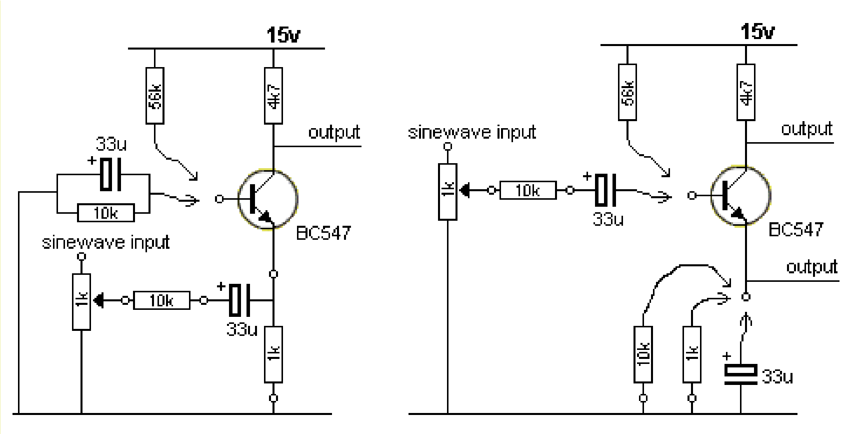


Fig 109.

Fig 109 shows the circuit for the trainer and how it can be wired to produce all the stages we have covered in this discussion. By feeding each stage with a sinewave at the input, you can view the output on a CRO and see how it works. This is only part of the picture to understanding the operation of each stage as the input and output impedances are also important and the third important thing is the effect of the capacitor(s) and/or electrolytics that connect one stage to another and/or those connected to the emitter to provide EMITTER BY-PASS.
We have already explained the advantage of a common-base stage (to connect a very low impedance device to an amplifying circuit) and the advantage of a common-collector (emitter-follower) circuit to drive a low-impedance load. e load.
A "trainer" only provides a fraction of the knowledge needed to understand "circuit-design" - but it helps. You must build "real-life" circuits to get a complete understanding.
The trainer above has lots of faults in its design. You cannot get a full understand of the common-base stage with 1k in the emitter. It should be 100R or less. The 10k feeding the 33u will attenuate the sinewave and is not needed.
The common-emitter stage does not provide any self-biasing option. The 56k base-bias is too low and the collector and emitters resistors are the wrong values to get any appreciable gain from the stage. When the 33u is put across the emitter resistor, the gain will increase enormously.
It would be much better to work on the circuits we have presented above and view the output on a CRO.
This trainer does not give you a full understanding of the operation of the three stages. (33u and 15v is rarely used in modern designs), I would give it a MISS.

Fig 110.

Fig 110 shows another trainer. It covers the common-emitter stage.
When a common-emitter stage drives a transformer or speaker as a load in the collector circuit, we want the sound to be free of distortion and to do this this we must bias the stage so the collector is at half-rail voltage when no audio is present.
This allows the transistor to turn ON and OFF to provide the maximum voltage-swing. If the transistor is not sitting at mid-rail, either the positive or the negative peaks of the signal will hit either the positive or negative rail and produce distortion - because the full excursion (height) will not be reproduced.
But biasing the transistor at mid-rail means the current though the speaker or transformer will be about half the peak current and this is wasted as it flows at all times, even when audio is not being processed. That's why this type of stage is not efficient and it heats up the output transistor considerably, even with no audio.
This type of circuit is called "CLASS-A" and the trainer above has a "Bridge" circuit as a pre-amplifier and is capacitor-coupled to a common-emitter stage as an output stage - driving a transformer - as a class "A" amplifier. Since transformers are expensive, difficult to purchase and add weight to a project, they have generally been replaced by complementary-symmetry push-pull class-B output stages.
All the features in this trainer have been covered in the circuits above.

Which circuit is best?

Fig 111 shows four different circuits driving a speaker. Which circuit is best??

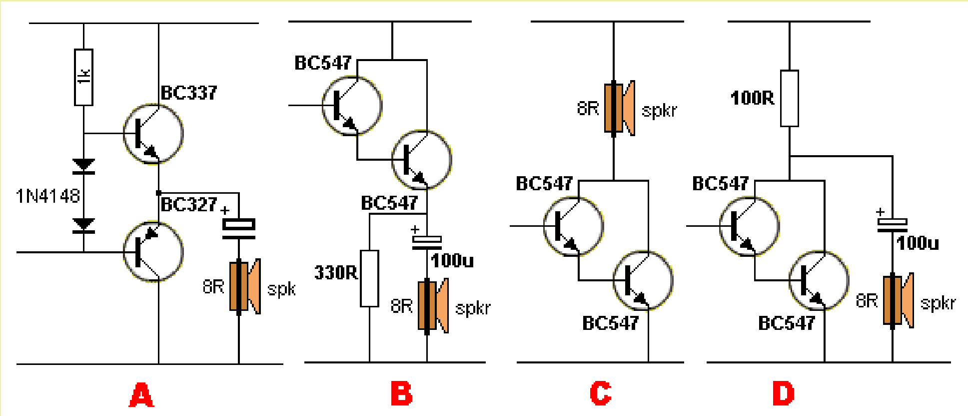


Fig 111.

The 4 circuits in **Fig 111** drive an 8 ohm speaker and are called **OUTPUT STAGES** or **DRIVER STAGES.** They are all different in performance and have different input voltage requirements.
Circuit A is really only a one transistor emitter-follower amplifier as the other transistor discharges the electrolytic.
However it is fully discharged and represents only a few ohms resistance (impedance) in series with the speaker. The input voltage-swing must be as large as possible (called rail-to-rail swing) to achieve the maximum output.
Circuit B is a two-transistor amplifier (called a **Darlington Pair**) and requires only a very small input current for the circuit to work, but a rail-to-rail voltage-swing. The speaker is AC coupled and only the audio current enters the cone and the cone is not displaced by any DC current. However the 100u is discharged via a 330R and the electrolytic is equivalent to a 330R in series with the speaker. The output from this circuit will be very low.
Circuit C is a **Darlington Pair** directly connected to a speaker. The input is very sensitive and requires less than 1v swing for full output. However DC flows through the speaker and will heat up the coil as well as shift the cone and maybe reduce the output capabilities of the speaker. The BC547 driver transistor will not be able to deliver much current. A BC337 is a better choice.
Circuit D is a high gain **Darlington stage** and has a sensitive input and requires less than 1v for full output. However the electrolytic is discharged via a 100R and this means it is equivalent to a 100R in series with the speaker.
The best circuit is "**A**" but it needs a pre-driver transistor to achieve the gain (amplification) of the other 3 circuits.

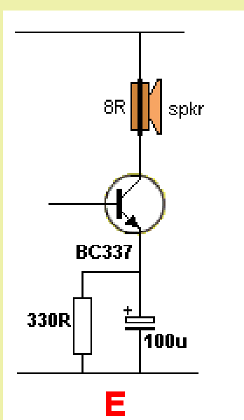


Fig 111a.

Fig 111a is a "Class-A amplifier" with an emitter resistor that is by-passed with a 100u capacitor. The quiescent (idle) current taken by the stage will be low due to the 330R emitter resistor but when a signal is delivered to the base, the transistor will operate as if the emitter is connected directly to the 0v rail. This means the stage will provide very good amplification while the quiescent current is quite low.
Note: **Fig111a** needs to have a base-bias resistor and a capacitor coupling the base to the previous stage, to qualify as a class-A amplifier. If the base-bias resistor is removed, the stage becomes "Class-C" where the stage uses the energy from the previous stage (via the capacitor) to "turn it on."

CLASSES

Here is a discussion on the type of output stages and the advantage and disadvantages of each stage. Output stages are classified as "class-A, class-B" etc and explain how current is "steered," or controlled, within a power amplifier before it is delivered to a speaker load.

Class A is the simplest, most basic topology. Reproduction of music requires speaker motion both in and out. To do this, amplifiers must "source and sink" current. In a Class A amp only one direction of current flow is used. It relies on the movement of the code to return it to the neutral position or movement in the reverse direction due to the inertia of the cone.

To reproduce a sinewave (or similar waveform) the output stage must be biased to half-rail voltage so the waveform can rise and fall. This means the output stage is consuming half-power when NO SIGNAL is being

delivered. The heat losses are high but the output is very high quality.

Class B uses two variable output stages, one to source current and the other to sink current.

This topology overcomes the poor efficiency of pure Class A, only delivering power as needed.

Both output stages turn completely off during the time when the signal passes from one output to the other. Time delay and low-level non-linearities cause some distortion, called "crossover distortion," during transition from source to sink output stages. This type of distortion is worst at low output levels. Pure Class B is only used in the lowest-cost, lowest-fidelity designs.

Class A/B is a combination of Class A and Class B. Using two variable output stages like Class B but keeping them from completely turning off, you get near Class B efficiency with near Class A's low-distortion performance.

Class C combines active devices with resonant magnetic components for high efficiency at radio frequencies. This topology is not used in audio-frequency designs. The output stage is not biased, but gets all its drive capability from a previous stage.

Class D uses source and sink output stages that consist of full-on or full-off switches. These output stages toggle from full sink to full source at a rate significantly higher than the highest audio frequency to be reproduced. The ratio of time sinking to time sourcing controls the audio output, with a 50% ratio delivering zero output.

Class D offers significantly higher efficiency than Class B. Losses in Class D designs are limited to turn-on time of the switching devices and resistive losses in these devices and output filtering.

Class D amps require more complex circuit designs with extensive shielding and filtering.

Class G & H are variations on Class B that use multiple source and sink output stages. Low-level signals are handled by one pair of output stages, while higher-level signals are handled by other pairs. Each pair is optimized for the power range it delivers.

More efficient amplifiers can deliver the same output power with smaller transformers and less heat sink.

Circuit complexity increases, which adds cost. Switching distortion similar to Class B's crossover distortion occurs at each output level transition.

Bridge Mode takes advantage of the fact that speaker loads can be driven differentially. Using separate amplifiers to drive both the positive and negative speaker terminals with opposite-polarity waveforms yields an effective doubling of the voltage swing for 4 times the power.

Provides high power levels using lower-voltage components.

Increased circuit cost/complexity and inability to ground reference either speaker lead.

FAULTS

Here is a text book containing a series of questions and answers.:
Self Teaching Guide
I have included it to show you that even electronics authors who have been in electronics for decades, make mistakes.
See the question on base and collector current for a 24v globe. The author has made no mention of the fact that the globe takes 6 times more current when turning ON. That's why you will find the circuit he designed, will not work.
He also describes a two transistor circuit where one transistor turns the other off. This is a very current-wasteful circuit.
He also describes the bleed current for the base (voltage-divider) for a circuit that does not need a voltage divider.

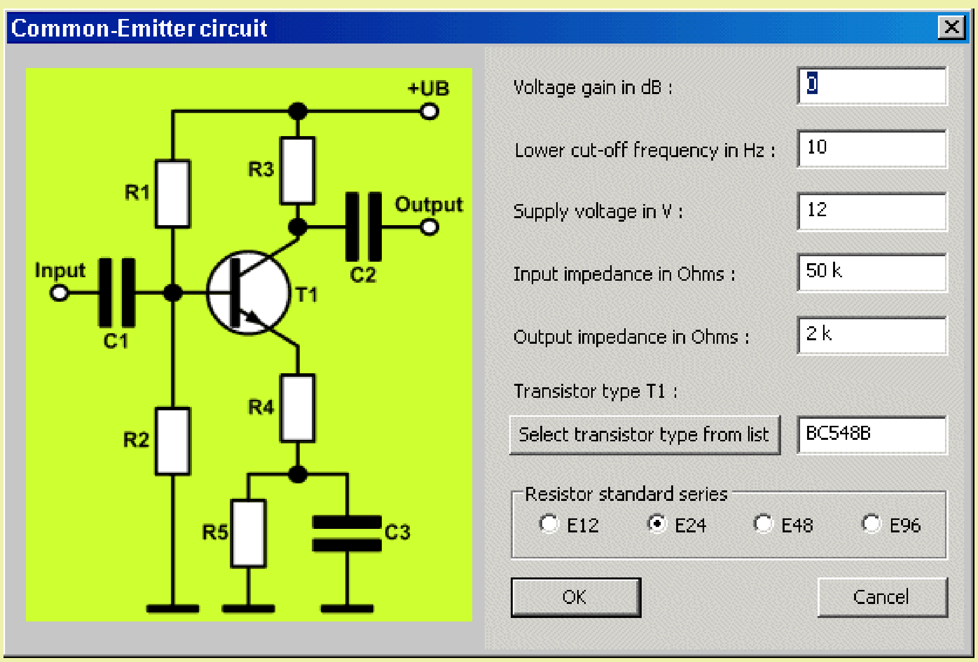
DESIGN SOFTWARE

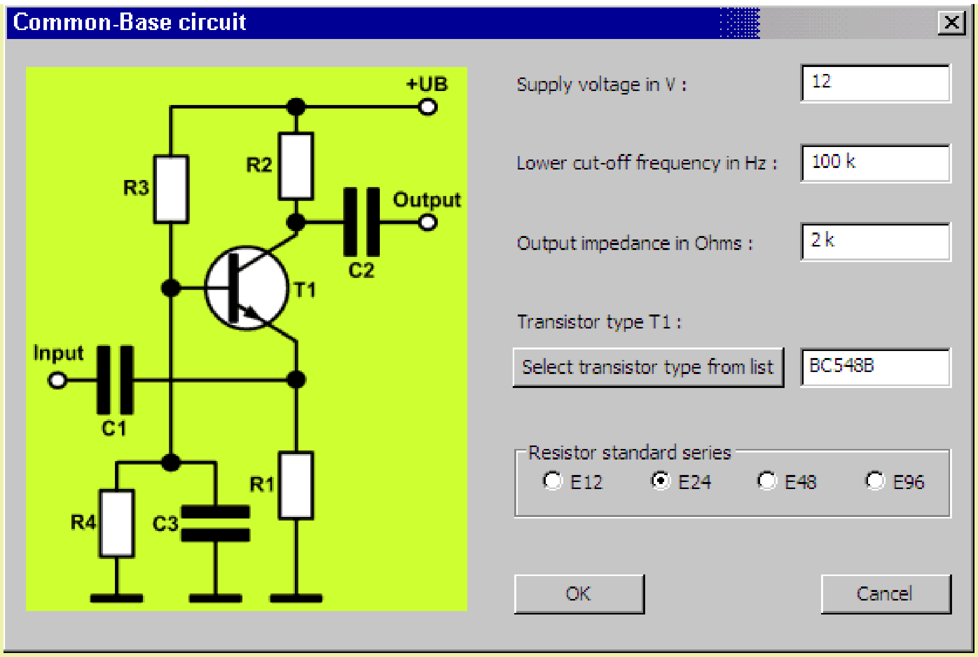
TransistorAmp software by Didaktik Software

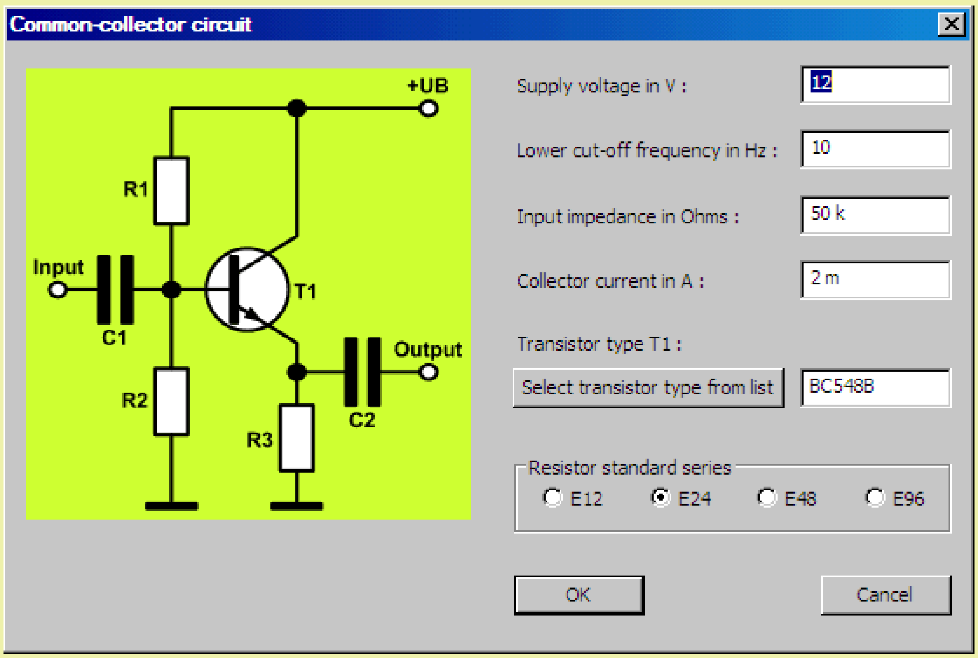
The following software allows you to design your own single-stage Common-Emitter, Common-Base or Common-Collector amplifier.
It has been created by **Didaktik Software**. This is version 1.1.1 created 23-6-2012
Download: **TransistorAmp** (.zip 520KB)
TransistorAmp unzips to TransistorAmp.msi (620KB) and will install on your computer with a desktop icon.
Or you can download: **TransistorAmp (.exe)** or **TransistorAmp (.rar)** Unzip .rar in a folder "TransistorAmp" and it will create TransistorAmp.exe Click on the file and the image above will appear.

How to use the software TransistorAmp

TransistorAmp is very easy to use. You start every design with the menu item: "**New Amplifier**". In the pull-down-menu you choose your desired circuit. You can choose between common-base-circuit, common-emitter-circuit and common-collector-circuit. After that you get a dialog, where you have to put in all parameters of your amplifier.
The following 3 images show the layout of the circuit you will produce:







For the selection of the transistor-type you can click on the button: "Select transistor type from ", and you will see a list of all supported transistor types. TransistorAmp supports some thousand transistor types - even some Germanium transistors. Select your desired transistor type and click OK. The selected transistor type will be displayed in the dialog. Both NPN and PNP transistors are supported.

When you have completed your input in the dialog, click OK and see the result. You see a window with your input data, the circuit, the component values and the most important parameters of the operation point. If you want to change your design, you only need to click again on "New Amplifier" and the circuit in the pull-down-menu. Your previous input data will be restored in the input dialog and you can change one or more parameters.ameters.

Note: for the Common-Collector amplifier: "Collector current in A" means: "Collector current in Amps." For 2mA, insert 0.002 etc.

Decibel (dB) Calculator

Decibels are defined as ten times the log of a power ratio. This calculator converts between decibels, voltage gain (or current), and power gain. Just fill in one field and the calculator will convert the other two fields.

dB= 20log(V1/V2)= 10log(P1/P2)

Decibels (dB)		

	Voltage Gain	Power Gain
Convert	Convert	Convert

When you are satisfied with the result, click on: "Result - Save". TransistorAmp saves all data in the result window to an HTML-file. You can open this file with a browser (e.g. Firefox or Internet Explorer), inspect it and print it.

Comment from a FORUM MEMBER (http://www.electro-tech-online.com/)
My boss once said to me: "The transistor will never "take-off" it is only equal to a triode (valve)."

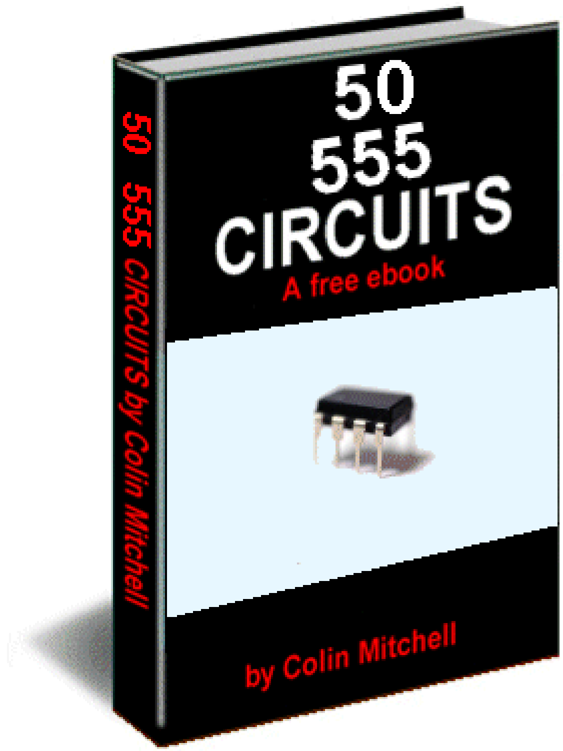
You can also learn a lot from our other eBook "200 Transistor Circuits." It is available in two parts:
1- 100 Transistor Circuits
101 - 200 Transistor Circuits
We also have 17 pages of circuits with faults:
Spot the Mistake: P1 P2 P3 P4 P5 P6 P7 P8 P 9 P10 P11 P12 P13 P14 P15 P16 P17

After reading all these discussions you will realise how little has been provided in the average text book on designing transistor stages. That's why these articles were produced. They explain this extremely important topic in a completely new way - one that even I can understand . . .
50 years ago I heard an engineer say: It is only a 3 leaded device, like a triode valve: "It will never succeed."

On the next page we cover connecting a "normal" or "standard or "common transistor" - called Bipolar Junction Transistor (BJT) to a Field Effect Transistor (FET).

P3


CD OF
TALKING ELECTRONICS
WEBSITE



For our other free eBooks,
Go to: **1 - 100 Transistor Circuits**
Go to: **101 - 200 Transistor Circuits**
Go to: **100 IC Circuits**

To learn about the development and history of the 555, go to these links:
http://semiconductormuseum.com/Museum_Index.htm - a general discussion about the development of the transistor
http://semiconductormuseum.com/Transistors/LectureHall/Camenzind/Camenzind_Index.htm - history of the 555 - Page1
http://www.semiconductormuseum.com/Transistors/LectureHall/Camenzind/Camenzind_Page2.htm - history of the 555 - Page2
http://www.semiconductormuseum.com/Transistors/LectureHall/Camenzind/Camenzind_Page3.htm - history of the 555 - Page3
http://www.semiconductormuseum.com/Transistors/LectureHall/Camenzind/Camenzind_Page4.htm - history of the 555 - Page4
http://www.semiconductormuseum.com/Transistors/LectureHall/Camenzind/Camenzind_Page5.htm - history of the 555 - Page5
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http://www.semiconductormuseum.com/Transistors/LectureHall/Camenzind/Camenzind_Page9.htm - history of the 555 - Page9
http://www.semiconductormuseum.com/Transistors/LectureHall/Camenzind/Camenzind_Page10.htm - history of the 555 - Page10

For a list of every electronic symbol, see: Circuit Symbols.

For more articles and projects for the hobbyist: **see TALKING ELECTRONICS WEBSITE**

Talking Electronics

See TALKING ELECTRONICS WEBSITE

email Colin Mitchell: talking@tpg.com.au

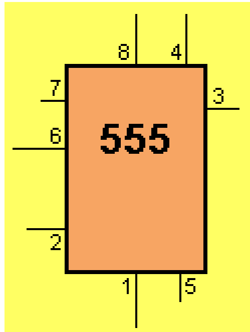
This set of 555 projects has increased to the largest on the web, with many circuits designed by me as a request from readers. The whole site has been copied by lots of other sites without any reference or acknowledgement to me. But you can see the circuits are mine by the way they have been drawn and none of the other sites keep updating with the latest additions.
This is the only site that teaches you how to learn and remember how a 555 works and this is very important when you want to design a new circuit.

CONTENTS

You will find many of these circuits "talked-about" and produced on bread-board (with videos) on: http://www.555-timer-circuits.com and: http://www.555-timer-circuits.com/forum

WHAT IS THE 555?

The 555 is an 8-pin chip that can be turned into lots of different things (building blocks).
The circuit inside the 555 is just an amplifier with 2 inputs and an output.
The parts you add to the chip determine the final result (effect).
In most cases you add a capacitor and resistor to produce a circuit known as a TIME DELAY CIRCUIT and the chip has a detection-pin and an amplifier (also called a power amplifier) to product an output.
It is not a "timer," "delay" or "oscillator" but is capable of being converted into these and maybe 100 other circuits.   Just call it the "555"



THE 555 CHIP

INTRODUCTION

This e-book covers the 555.

The 555 is everywhere and it is one of the cheapest and most-rugged chips on the market. It comes as a TTL 555 and will operate from 4v to about 16-18v. (don't use less than 5.5v) It costs from 20 cents (eBay) to $1.20 depending on the quantity and distributor. The circuitry inside the chip takes about 10mA - **even when the output is not driving a load**. This means it is **not suitable** for battery operation if the chip is to be powered ALL THE TIME.

The 555 is also available as a CMOS chip (ICM7555 or ICL7555 or TLC555) and will operate from 2v to 18v and takes 60uA when the circuitry inside the chip is powered. The "7555" costs from 60 cents (eBay) to $2.00

We call the TTL version "555" and the CMOS version "7555." This is called **ELECTRONICS JARGON**.

The 555 comes as a single timer in an 8-pin package or a dual timer (556) in a 14 pin package.

The 7555 comes as a single timer in an 8-pin package or a dual timer (7556) in a 14 pin package.

The 555 and 7555 are called TIMERS or Timer Chips. They contain about 28 transistors and the only extra components you need are called TIMING COMPONENTS. This is an external resistor and capacitor. When a capacitor is connected to a voltage, it takes a period of time to charge. If a resistor is placed in series with the capacitor, the timing will increase. The chip detects the rising and falling voltage on the capacitor. When the voltage on the capacitor is 2/3 of the supply the output goes LOW and when the voltage falls to 1/3, the output goes HIGH.

We can also do other things with the chip such as "freezing" or halting its operation, or allowing it to produce a single HIGH-LOW on the output pin. This is called a "ONE-SHOT" or MONOSTABLE OPERATION - but it still takes 10mA while "sitting around".

When the chip produces an output frequency above 1 cycle per second, (1Hz), the circuit is called an OSCILLATOR and below one cycle per second, it is called a TIMER.

But the chip should not be called a "**555 Timer**," as it has so many applications. That's why we call it a "**555**." (triple 5)

Another thing you have to be aware of is the voltage on output pin 3. It is about 1-2v LESS THAN rail voltage and does not go to 0v (about 0.7v for 10mA and up to 1900mV for 200mA sinking current). For instance, to get an output swing of 10v you will need a 12.6v supply. In "electronic terms" the 555 has very poor sinking and sourcing capabilities.

One way to understand how the chip operates is to remember that pin 7 goes LOW when pin 3 (the output pin) goes LOW. When pin 3 goes HIGH, pin 7 goes "open circuit" (it does not go HIGH - it goes HIGH IMPEDANCE).

When in 4 is taken LOW, (it needs to be as low as 0.5v) the chip stops operating, but it still takes 10mA.

For photos of nearly every electronic component, see this website:
https://www.egr.msu.edu/eceshop/Parts_Inventory/totalinventory.php

You can also search the web for videos showing the 555 in action.
Here are a few:
Making A 555 LED Flasher – Video Tutorial
Three 555 LED Flasher

[555 Timer Flasher](#)
[Fading LED with 555 timer](#)

Each website has lots more videos and you can see exactly how the circuits work. But there is nothing like building the circuit and that's why you need to re-enforce your knowledge by ACTUAL CONSTRUCTION.

Learning Electronics is like building a model with Lego bricks. Each "topic" or "subject" or "area" must be covered fully and perfectly, just like a Lego brick is perfect and fits with interference-fit to the next block. When you complete this eBook, you can safely say you will have mastered the 555 - one more "building block" under your belt and in the process you learn about DC motors, Stepper motors, servos, 4017 chips, LEDs and lots of other things. Any one of these can take you off in a completely different direction. So, lets start . . .

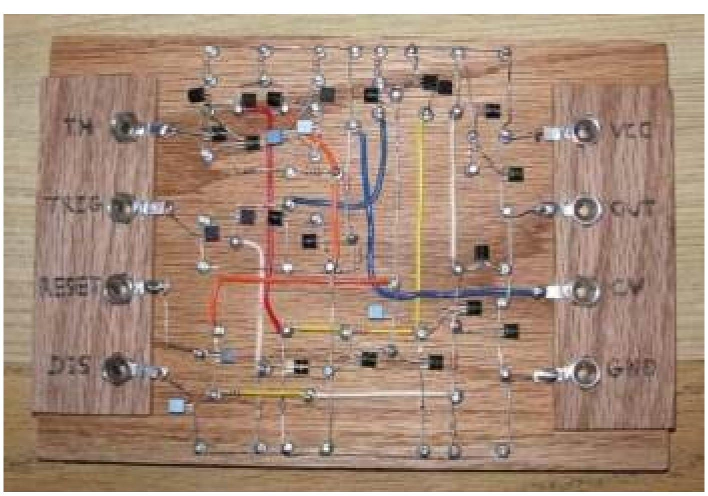
Colin Mitchell
TALKING ELECTRONICS.
talking@tpg.com.au

To save space (and get everything on a single page) we have not provided lengthy explanations of how any of the circuits work. This has already been covered in TALKING ELECTRONICS Basic Electronics Course, and can be obtained on a CD for $10.00 (posted to anywhere in the world). See Talking Electronics website (http://www.talkingelectronics.com) for more details on the 555 by clicking on the following four pages: **555-Page 1** **555-Page 2** **555-Page 3** **555-Test**
Many of the circuits have been designed by Colin Mitchell: **Music Box**, **Reaction Timer Game**, **Traffic Lights**, **TV Remote Control Jammer**, **3x3x3 Cube**, while others are freely available on the web. But this eBook has brought everything together and covers just about every novel 555 circuit. If you think you know everything about the 555, take the **555-Test** and you will be surprised!

SI NOTATION

All the schematics in this eBook have components that are labelled using the System International (SI) notation system. The SI system is an easy way to show values without the need for a decimal point. Sometimes the decimal point is difficult to see and the SI system overcomes this problem and offers a clear advantage.
Resistor values are in ohms (R), and the multipliers are: k for kilo, M for Mega.
Capacitance is measured in farads (F) and the sub-multiples are u for micro, n for nano, and p for pico. Inductors are measured in Henrys (H) and the sub-multiples are mH for milliHenry and uH for microHenry.
A 10 ohm resistor would be written as 10R and a 0.001u capacitor as 1n.
The markings on components are written slightly differently to the way they are shown on a circuit diagram (such as 100p on a circuit and 101 on the capacitor or 10 on a capacitor and 10p on a diagram) and you will have to look on the internet under **Basic Electronics** to learn about these differences.

Here's a 555 built from transistors by Eric Schlaepfer in honor of Hans Camenzined, who invented the 555:



You can build your own 555 from this Instructable:
http://www.instructables.com/id/Build-Your-Own-555-Timer/

Or buy a kit for $35 from Evil Mad Scientist:
http://shop.evilmadscientist.com/productsmenu/tinykitlist/652

This kit is ideal for a school science project.
Here is the circuit and assembly instructions.

WARNING!!

Before making any 555 project, remember the chip takes about 10mA **ALL THE TIME** and cannot be turned off.
The output (the "driving power") of a 555 is about 200mA while the CMOS versions are only about 50mA.
The chip is not really suited for doorbells and circuits as the 10mA will rapidly drain the battery.
The 555 does not like 5v supply. Use 6v supply (minimum) when designing a circuit and then see if it works on 5v. This is a REAL TRAP !!!!!

NEW! FROM TALKING ELECTRONICS

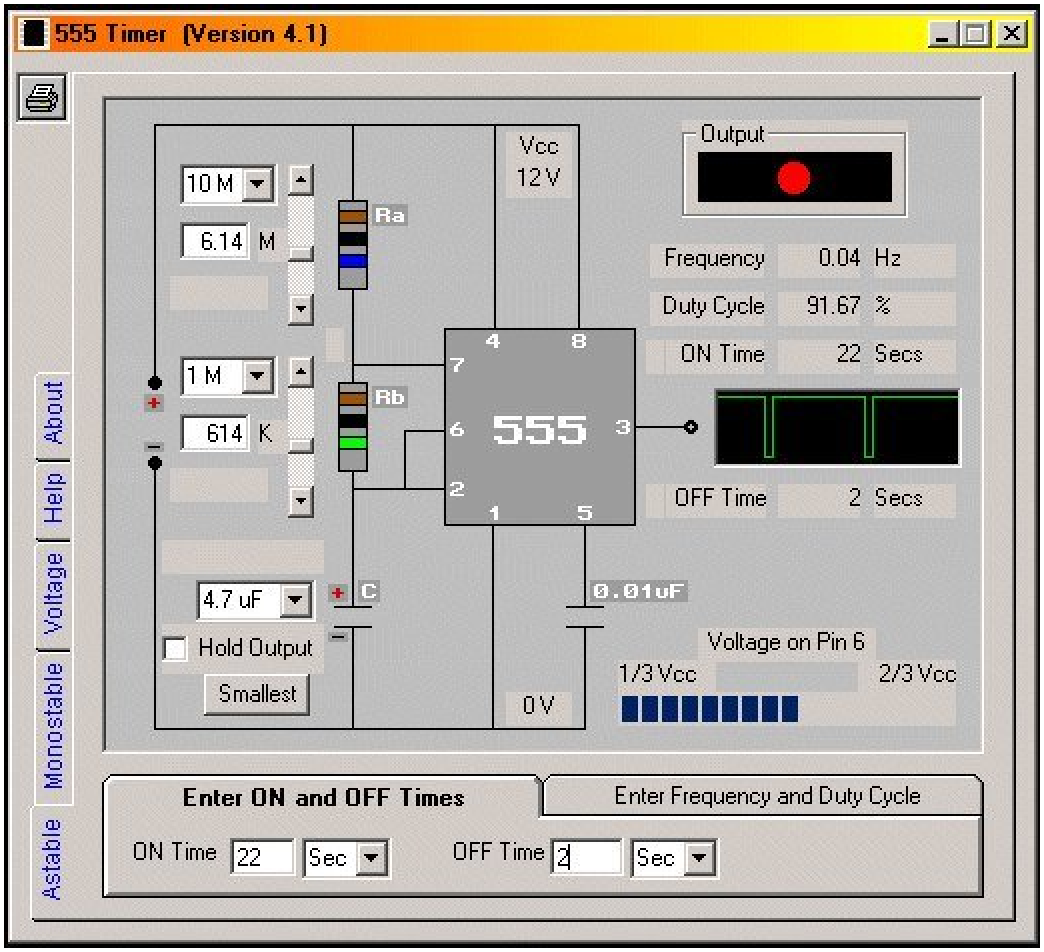
A new range of 555 chips have been designed by Talking Electronics to carry out tasks that normally need 2 or more chips.
These chips are designated: TE 555-1, TE555-2 and the first project to use the TE 555-1 is **STEPPER MOTOR CONTROLLER TE555-1**.

It's a revolutionary concept. Instead of using an old 8-pin TTL 555 chip, you can use a new TE555-1,2,3 8-pin chip and save board space as well as components. These new chips require considerably less external componentry and the possibilities are endless. Depending on the circuit, they can have a number of timing and frequency outputs as well as a "power-down" feature that consumes almost no current when the circuit is not operating. See the first project in this series: **STEPPER MOTOR CONTROLLER TE555-1**.
See also: **Stepper Motor Controller** project

See also TE 555-2 TE555-3 TE 555-4 TE555-5

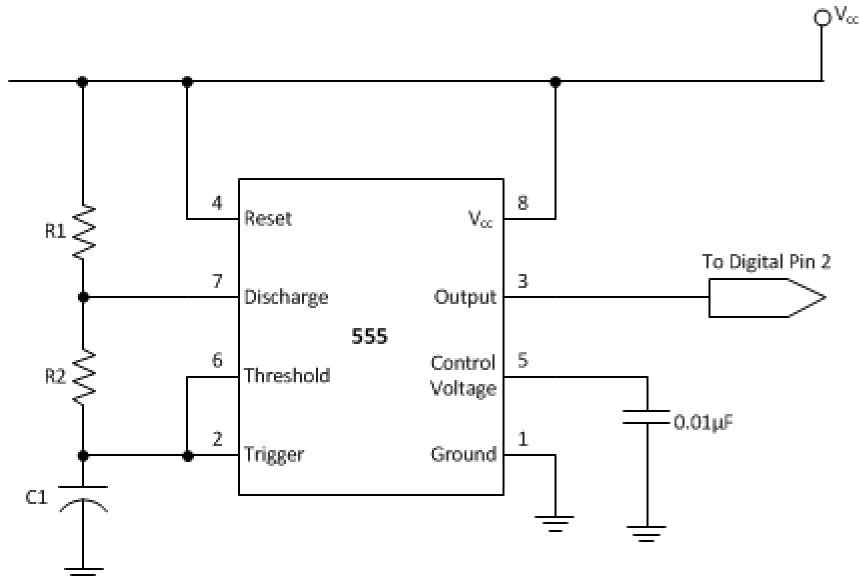
555 TIMER CALCULATOR

A program to work out the values for a 555 in Astable or Monostable mode is available from Andy Clarkson's website:
http://555-timer-circuits.uk/
555-Timer.zip (987KB). Name a folder: "555 Timer." Unzip and run "555 Timer setup.exe"
Setup will produce a desktop icon. Click on icon for program. Set the voltage for the 555 then use the Astable or Monostable tabs to design your circuit. Read the Help screen to understand the operation of: "Hold Output" and "smallest."



Here is another 555 calculator by Jeff:

555 Timer Calculator



This calculator will provide a number of component values for the delay you want or the frequency.
You can specify “10ms” or “4.5kHz” in the text fields.

How often do you want the timer to produce an output? [ ] seconds

What frequency do you want the timer to operate at? [ ] Hertz

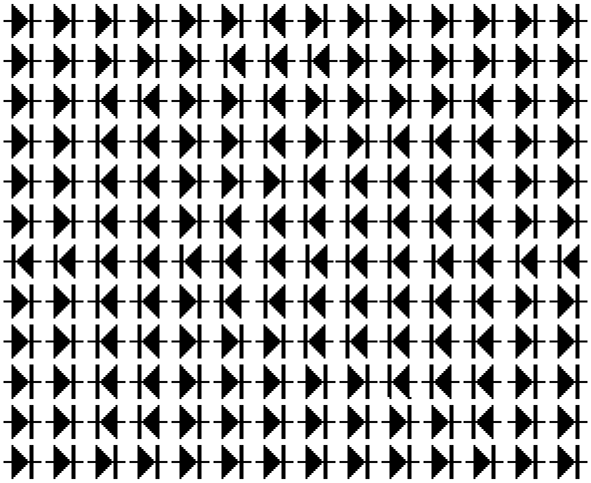
7555 CMOS CALCULATOR see 7555

The 555 comes in a low-power CMOS version. The drive-current from pin 3 is less than the TTL "555."
At 5v, a 7555 will deliver 2mA and sink only 8mA
At 12v a 7555 will deliver 10mA and sink 50mA
At 15v a 7555 will deliver 100mA and sink 100mA
Use the following 7555 calculator to find the OUTPUT FREQUENCY in Astable mode or OUTPUT TIME in Monostable mode:
7555 CMOS Calculator

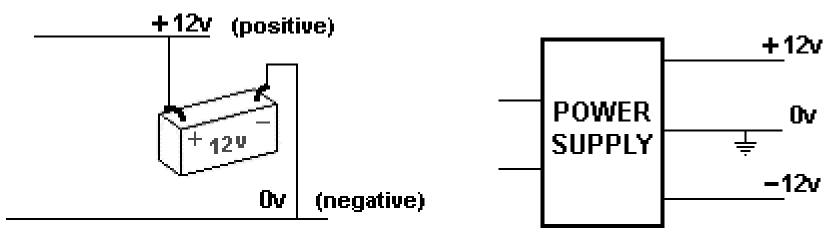
Here's a 555 made with 22 transistors by Malcolm Faed. See his video.

See his Electric Vehicle website.

How are your powers of observation?
Can you find the LED:



THE POWER SUPPLY



Sometimes you will see a circuit as shown in the **first diagram** with 12v or +12v on the top rail and 0v or a negative sign or the word "negative" on the bottom rail. In **this case** the word negative means earth or "chassis of a car" and we commonly refer to this as "negative earth" or "negative chassis."
In the **second diagram**, the output from a power supply has a positive 12 volts and a negative 12v with the 0v rail in the middle. In **this case** the negative 12v rail is twelve volts BELOW the earth rail and that's why we call it the NEGATIVE RAIL.
This means that when you hear "Negative Rail," you need to work out if it means the negative terminal of a battery (as in the first case - meaning 0v or earth) or if the voltage is below zero volts (as in the second case).

SQUARE WAVE OSCILLATOR KIT

A Square Wave Oscillator Kit is available from Talking Electronics for under $10.00. See full details of circuit below.

(This link will send an email to Colin Mitchell and you will be advised of costs and how to send money via Paypal or credit card.)

Or email Colin Mitchell: talking@tpg.com.au

555 KIT

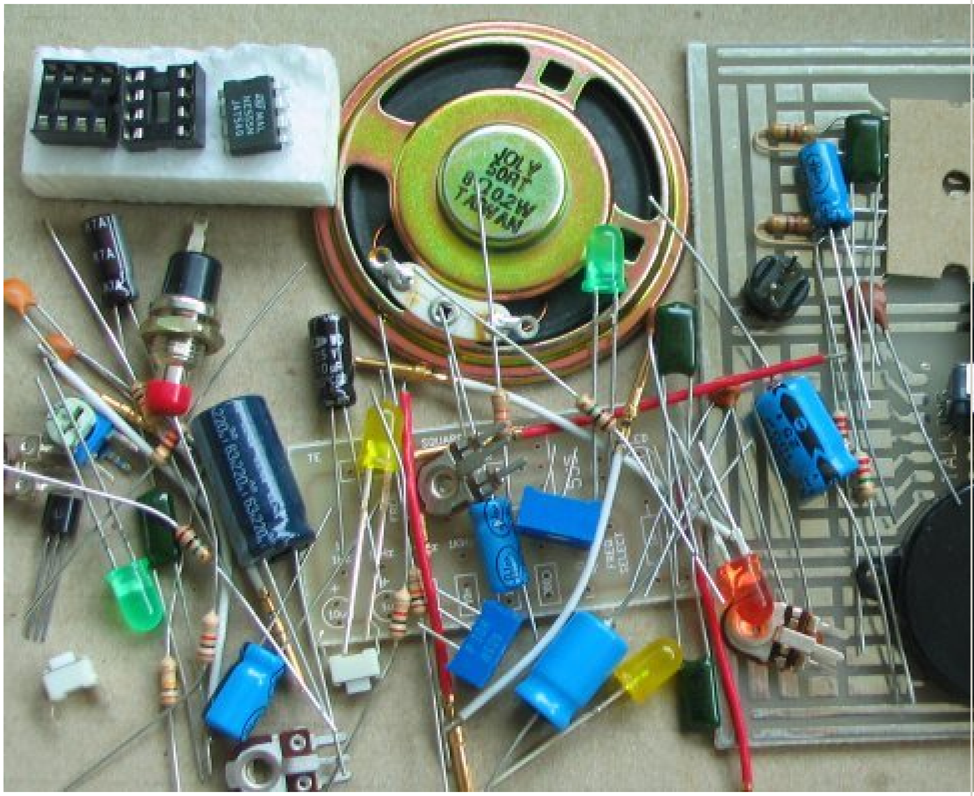
A kit of components to make many of the circuits described in this eBook is available for $10.00 plus $7.00 post.

Or email Colin Mitchell: talking@tpg.com.au

The kit contains the following components:
(plus **extra** 30 resistors and 10 capacitors for experimenting), plus:

2 - 220R
2 - 1k
2 - 4k7
2 - 10k
2 - 33k
2- 100k
2 - 1M
1 - 10k mini pot
1 - 100k mini pot
2 - 10n
2 - 100n
1 - 10u electrolytic
1- 100u electrolytic
2 - 1N4148 signal diodes
2 - BC547 transistors
1 - BC557 transistor
1 - 555 timer chip
1 - 8 pin IC socket
1 - red LED
1 - green LED
1 - orange LED
1 - mini 8R speaker
1 - mini piezo
1 - LDR (Light Dependent Resistor)
1 - 10mH inductor
1 - push button
1 - tactile push button
1 - **Experimenter Board** (will take 8, 14 and 16 pin chips)

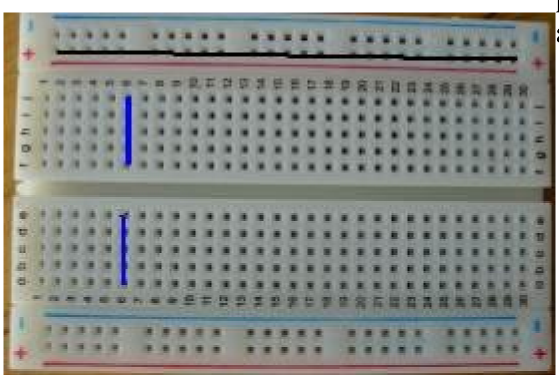
BUY NOW

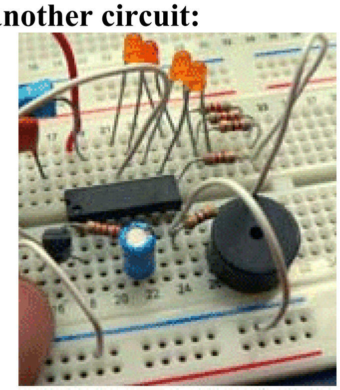


Components for 555 Kit

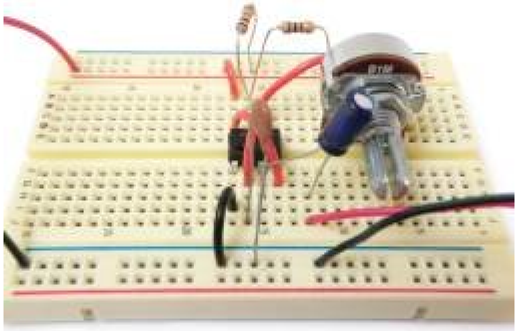
There are more components than you think.
All kits contain more components than on the list.
555 Kit: $10.00 plus $7.00 postage

You can also get a breadboard and 30 jumper leads for $5.00 so you can plug the parts into the board and re-use them for another circuit:





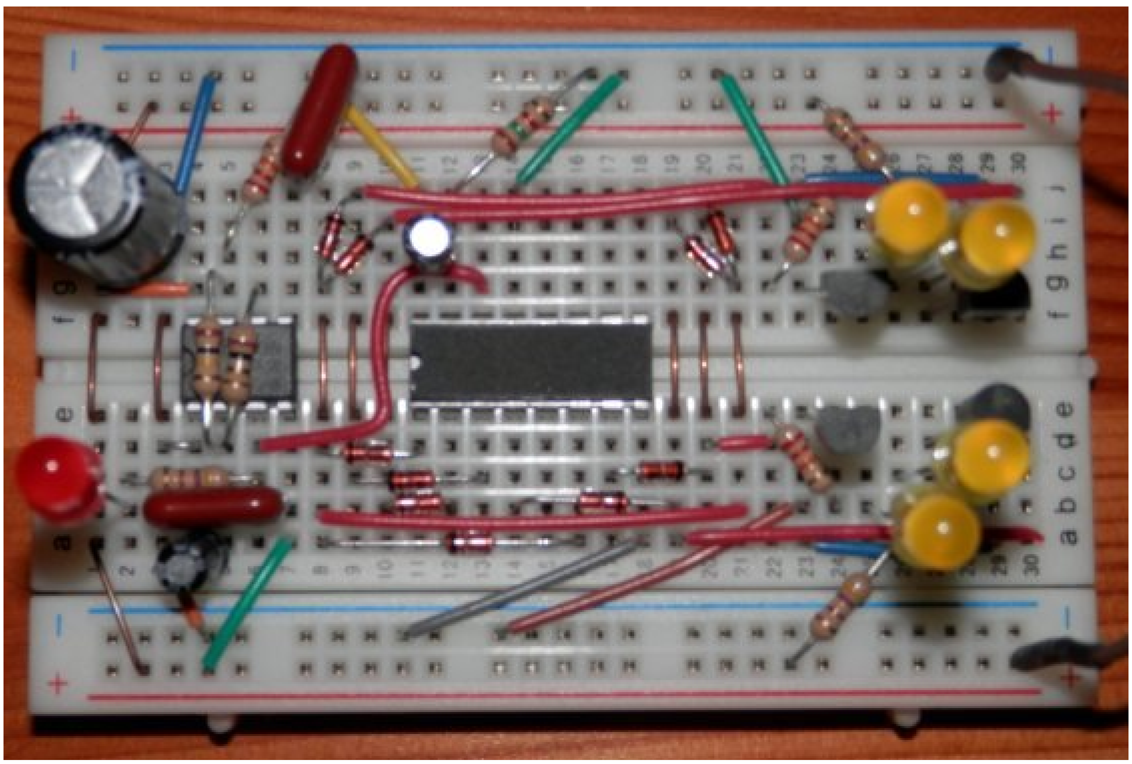
The photo shows a number of components fitted to the breadboard.



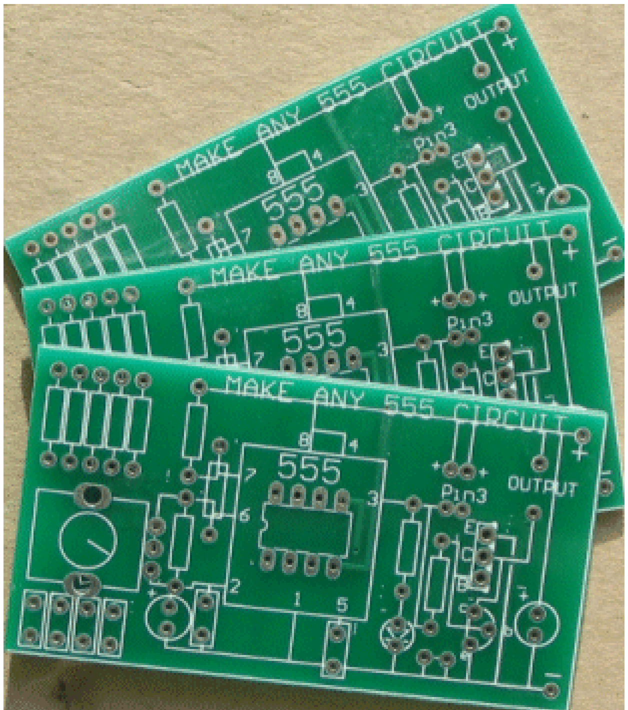
This is the breadboard you get.

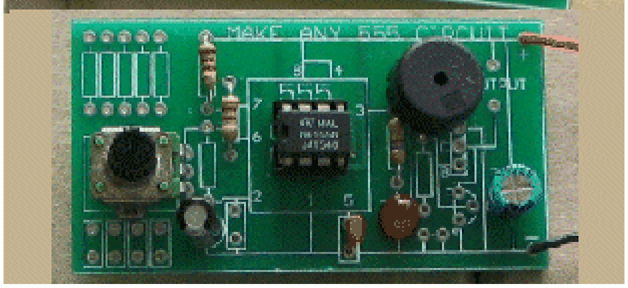
These are the 30 jumper leads that come with the breadboard

Here is a project from Franz Bachler, using a 555 and 4017 to drive 4 orange LEDs. He has used the bread-board to make a very neat project. The only problem is: he has cut the leads of the components and some of them will only fit between three holes. This may be a problem when you make the next project.
Email: Colin Mitchell to get the breadboard for $5.00 with the TRANSISTOR KIT or 555 KIT (see above).
You can make this project with MAKE A 555+4017 DISPLAY. The kit has 3 different displays that plug into the main board to get a range of different effects.



This is what you can do with the breadboard.

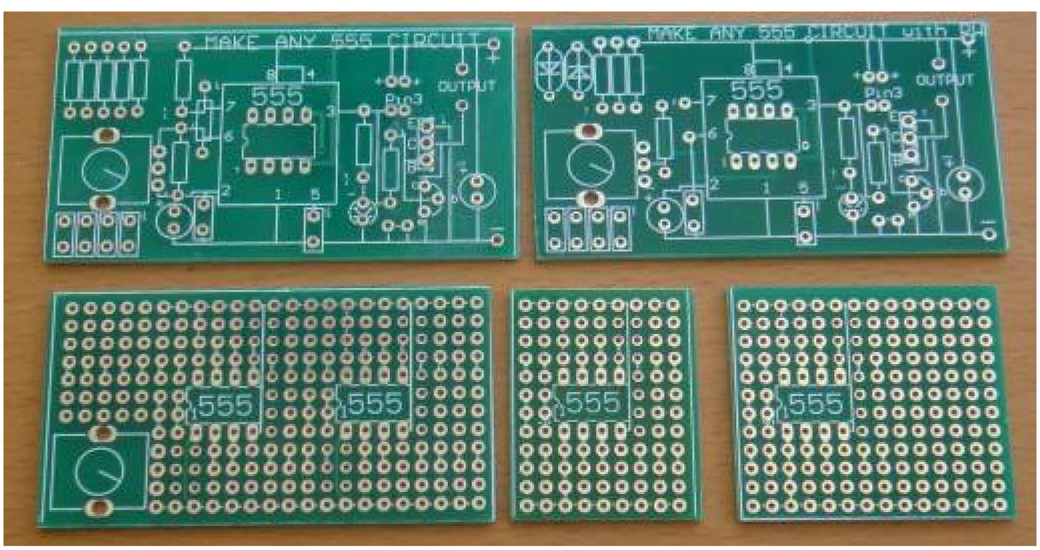




A set of components for **MAKE ANY 555 PROJECT** is just $5.00 extra
See Guitar Tuner Project
and Automatic Garden LED Strip Project

NEW !

5 Different boards are now available for $10.00 USD posted.

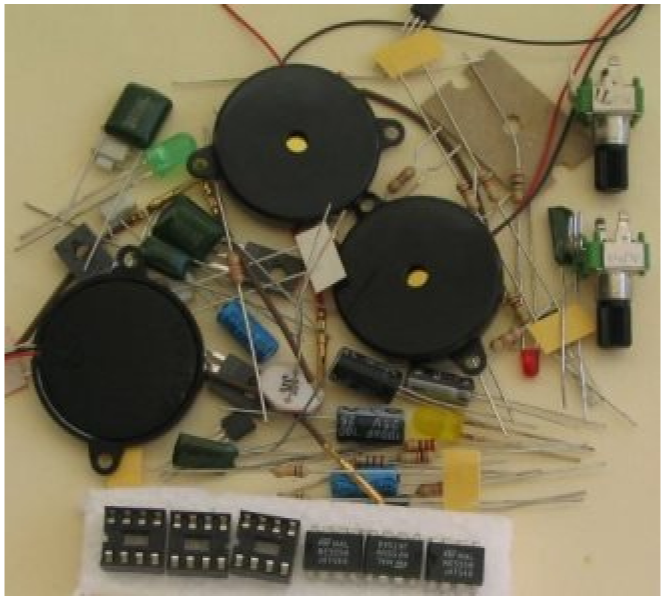


Please log into your paypal account and send a payment to
talking@tpg.com.au for $10.00 USD

And send your name and address and I will send the item(s). Let me know that you want the 5 different 555 boards for $10.00 posted.

Colin

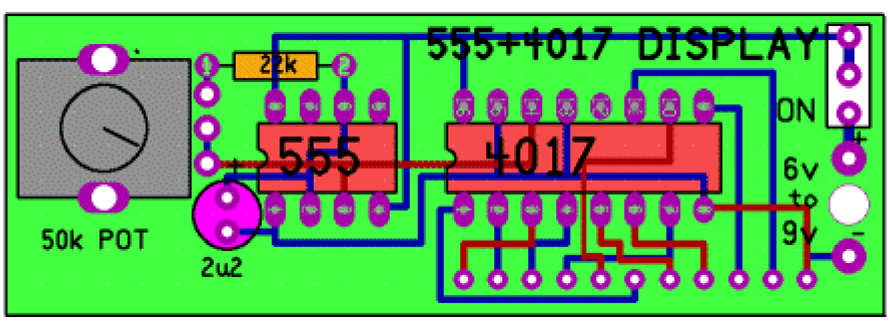
The parts include:
2 - 220R
2 - 1k
2 - 4k7
2 - 10k
2 - 33k
2 - 47k
2- 100k
2 - 1M
1 - 10k mini pot
1 - 100k mini pot
2 - 10n
2 - 100n
1 - 10u electrolytic
2- 100u electrolytic
1 - 1N4148 signal diodes
3 - BC547 transistors
3 - 555 timer chips
3 - 8 pin IC sockets
1 - red LED
1 - green LED
1 - orange LED
3 - mini piezos
1 - LDR (Light Dependent Resistor)
3 - slim tactile push buttons
Kit: $5.00 [VALUE: $6.50]

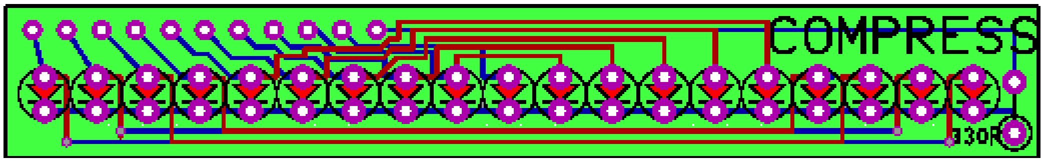

These parts will help you build many of the 555 circuits presented below.

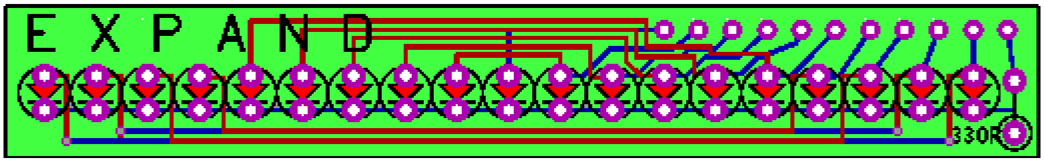
3 x Make any 555 Project PC boards $10.00 plus $5.00 components: $15.00 (post FREE)

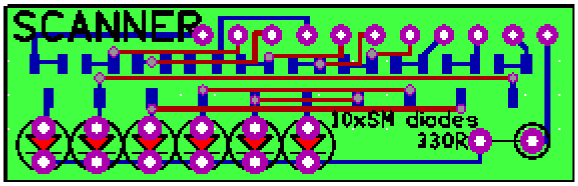
MAKE A 555+4017 DISPLAY $4.50

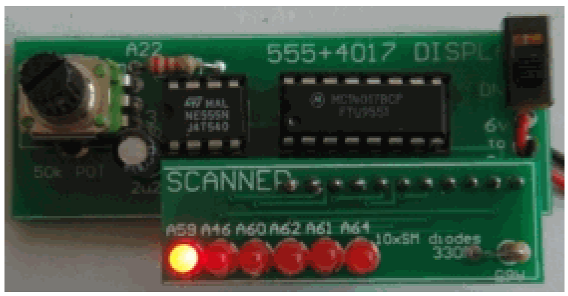
Make you own RUNNING LED DISPLAY with this 555+4017 PC board. It comes with 3 display boards that plug into the main board to produce an expanding or compressing effect, as well as a 6-LED KITT SCANNER. email Colin Mitchell: talking@tpg.com.au



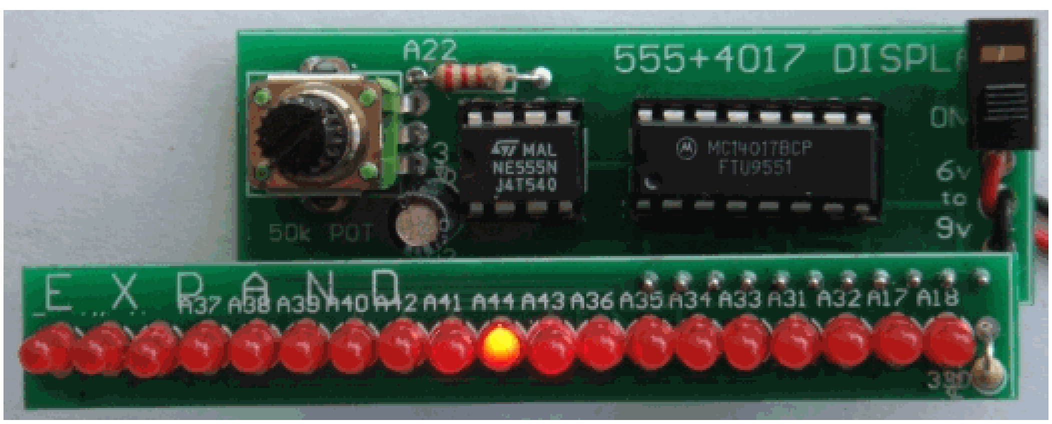








The Scanner - called Kitt Scanner



555 EXPAND

You also get COMPRESS - all instantly interchangeable

A set of components for this project is just $7.50 extra. This includes 44 LEDs, 20 surface mount diodes, 50k pot, 2u2, 22k, 555, 4017, IC sockets, 11 machine pins, 33 double-ended pins, slide switch, and battery snap.

BUY NOW

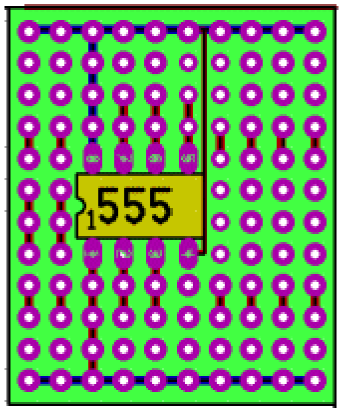
Make 555+4017 Project (with 3 display boards) $4.50
Set of components: $7.50
plus $4.00 postage.

We have everything for the hobbyist and engineer to build a 555 circuit on a Printed Circuit Board. This is the latest edition to the range:

BUY NOW

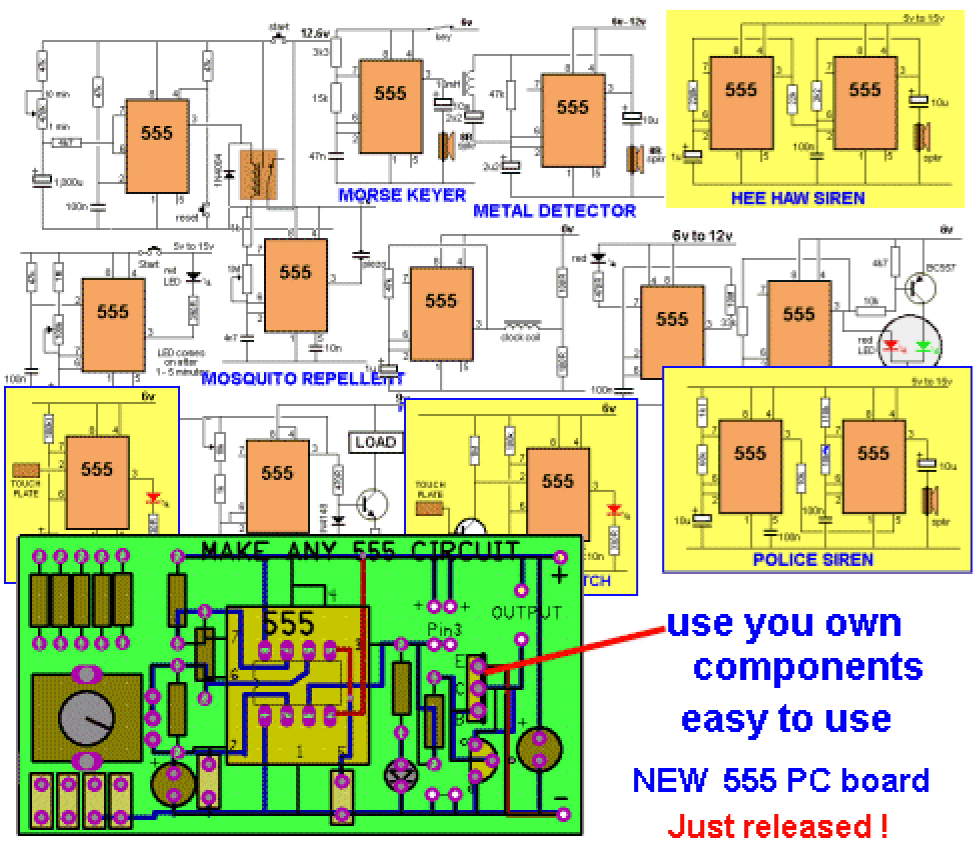
RIX BOARD $1.50each

for $5.00 plus $4.00 postage.   email Colin Mitchell: talking@tpg.com.au



555 MATRIX BOARD

The 555 IC is already "wired up" and some of the lands are connected to make fitting components easy. The overlay on the board shows you the wiring.
Get the set of components above for $5.00 extra and you will be able to make 3 different projects.

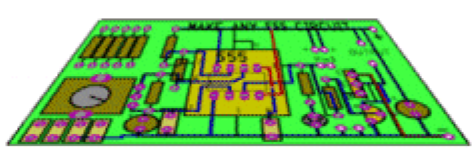


use you own components easy to use

NEW 555 PC board

Just released !

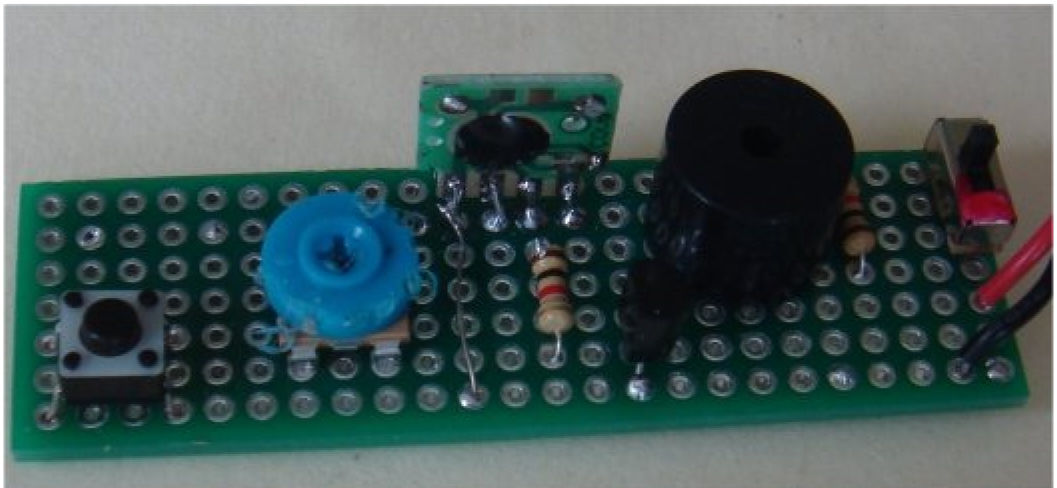
Make ANY 555 circuit just $10.00 for 3 boards . . . post free!!

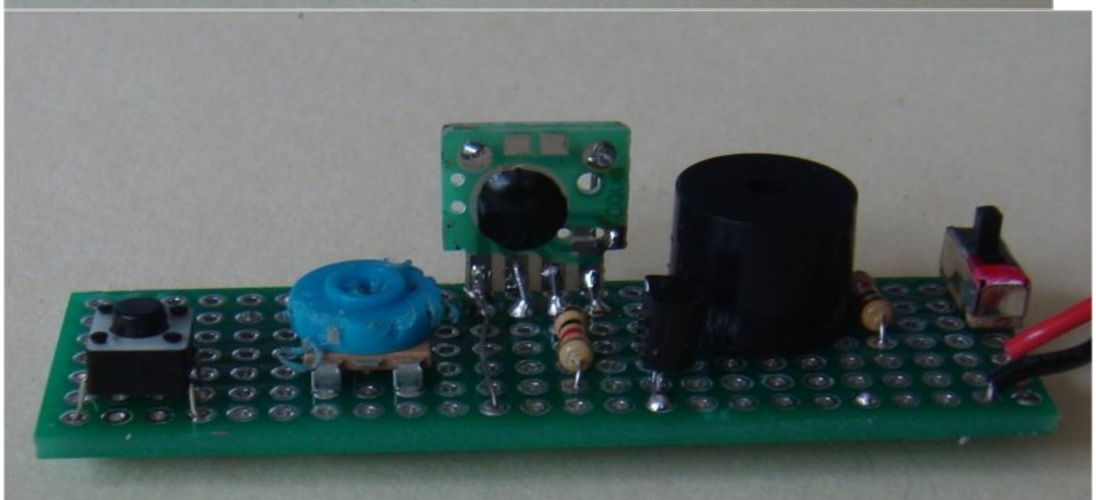


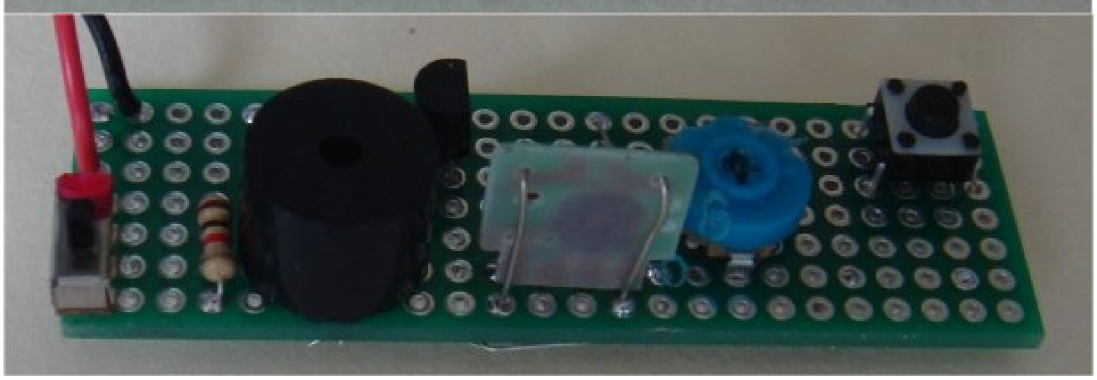
Click HERE to order your 3 x 555 PC boards for $10.00 post free. Use your own components and build lots of different circuits . . . set of components . . . just $5.00 extra !!
The set of boards has been increased to FIVE for $10.00 and you will get 5 when you place an order.

LONG DELAY TIMER

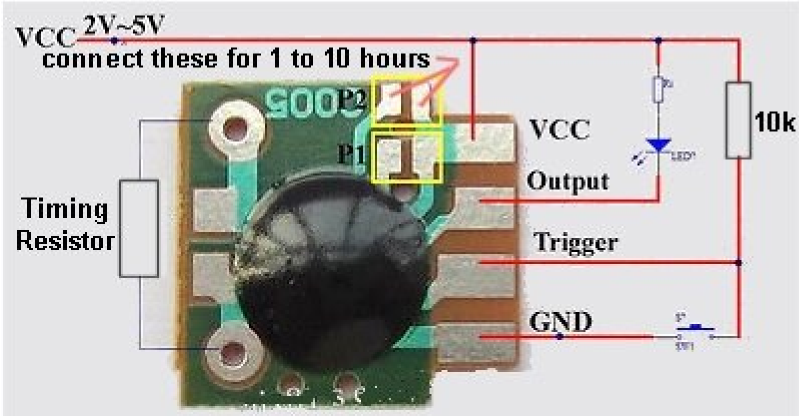
The 555 does not produce times longer than about 60 minutes and a new chip on the market produces times up to 1,000 hours. It is called C005. Here is the prototype where we tested the chip:







Back of the timer module showing the two wires for the pot.

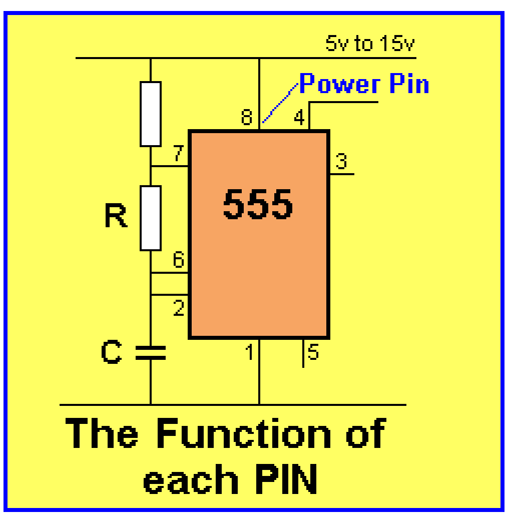


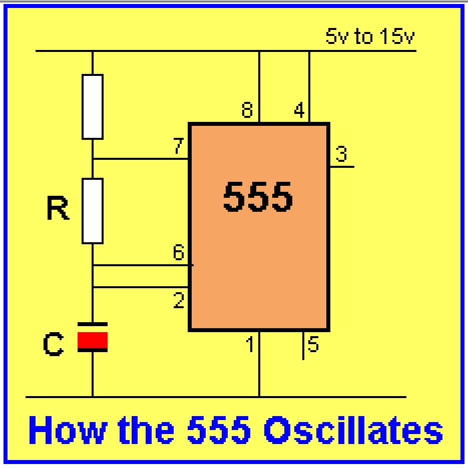
Connect the two top pads to produce 1 to 10 hours

A kit is available for $8.00 (plus postage) **and comes with all components and a printed circuit board with all parts clearly shown on the overlay. The pot is marked with 1 to 10 hours and this will be ideal for most applications. The tactile button starts the timing and the buzzer sounds when the time is up. Two output pins are also provided on the PC board to connect to other devices to turn them ON.**
The output of the board turns ON a device such as a relay, after say 5 hours, and the contacts on the relay will turn the device OFF. The buzzer on the board will let you know the 5 hours is up.
The project is connected to 3 x AA cells (4.5v) (in a battery box)
Consumption when timing: 100uA
Output: pull-up 3mA pull-down 30mA
Connecting the pads at P1 and also the pads at P2 increases the delay by 8 times, making the timing up to 80 hours. (but don't let P1 pads touch P2 pads). Changing the pot to 20M creates 1,000 hours.
email Colin Mitchell: talking@tpg.com.au for payment for the kit via paypal.

HOW A 555 WORKS

To design a 555 circuit you must know how a 555 IC works. Here is an explanation:

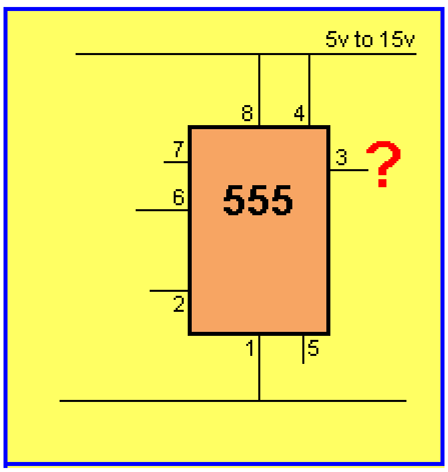




The capacitor charges between 33% and 66% of tail voltage. When the capacitor is 66%, pin 6 detects the voltage and makes pin 7 go LOW. The capacitor discharges to 33% and pin 2 detects the voltage and makes pin go HIGH (actually pin7 goes OPEN) and the capacitor charges to 66% to repeat the cycle.

LET'S START:

1. Connect the 555:



UNKNOWN STATE

We start with pins 2 and 6 NOT CONNECTED. This is called the UNKNOWN STATE because the chip is not getting any information and the output is UNKNOWN.
The inputs are called "FLOATING." Inputs must NEVER be "FLOATING."

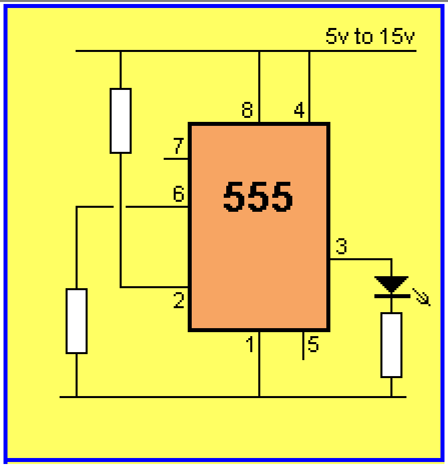
2. Connect Pins 2 and 6:

We start by connecting pins 2 and 6 as shown:

This is also called the UNKNOWN STATE because Pin 2 detects a LOW to make the output HIGH and pin 6 detects a HIGH to make the output LOW.
The output will be HIGH or LOW depending on which pin is detected first.
The output is controlled by a BUILDING BLOCK called a FLIP FLOP or TOGGLE or SWITCH or BI-STABLE LATCH. It will remain "locked" or in a stable state and it will take a voltage of about 33% or more of rail voltage to change the state via pins 2 or 6.
In most cases the output will "flip over" to the state with the output LOW. If you delay pin 2 by 1uS, the output will go HIGH, indicating pin 2 is detected first to make the output HIGH.

3. Toggle (or change) the output:

The output can be changed by using pin 2 or 6.

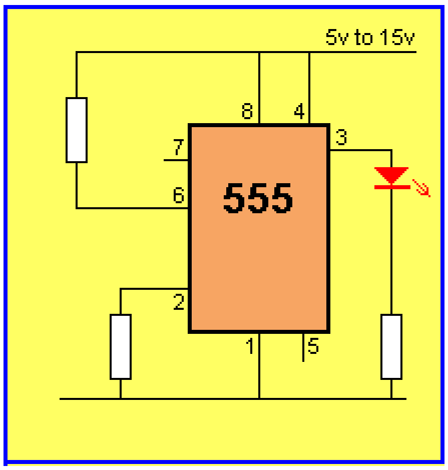


Pin 2 and Pin 6 change output

The output changes immediately, the animation is a "slow-down."

4. The output:

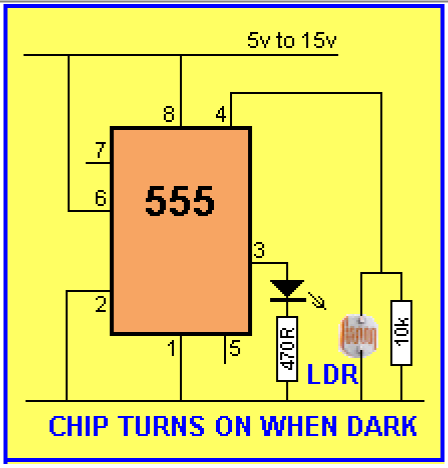
If we make pin 2 LOW and Pin 6 HIGH, both pins are trying to change the output of the chip and pin 2 WINS !!!   The output is HIGH !!



Pin 2 WINS !!

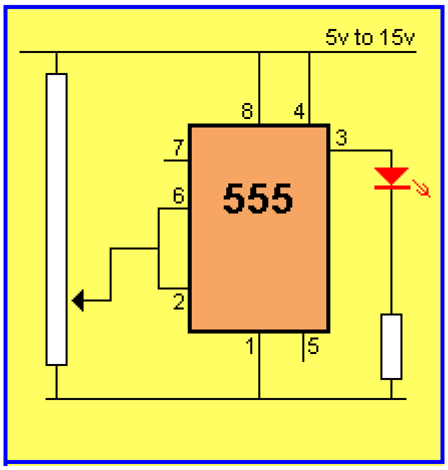
4a. The RESET PIN

Pin 4 is the reset pin. When it is taken to the positive power rail, the chip "works." When it is taken to 0v rail, the chip "freezes" and pin 3 instantly goes LOW, (even if it is halfway through a timing cycle). But the current taken by the chip remains at 10mA and you cannot use this pin to "turn off the current taken by the chip."
If pin is unconnected, it will allow the chip to operate as the internal circuitry puts a "High" (950mV) on the pin.
But the Reset Pin is more complex.
When nothing is connected to pin 4, it has a voltage of about 950mV on it and it will deliver about 350uA. This is due to the circuitry inside the chip.
It must be taken below 500mV to turn the chip off.
A 2k7 resistor connected to pin 4 will turn the chip off.
A 3k3 resistor connected to pin 4 will **NOT** turn the chip off.
This means pin 4 is generating a voltage (and current) and we can use this feature to turn the chip OFF via a Light Dependent Resistor (LDR).
If we connect an LDR to pin 4, it will require a very bright light to reduce the resistance of the LDR to less than 3k3.
By adding a 10k to the circuit, we help the LDR produce a combined resistance less than 3k3 and the circuit will work in a normal lounge-room or bedroom. When the LDR sees illumination from a room-light, it will turn the chip off.
You can try values as low at 4k7 to make the chip MORE sensitive.
In the following circuit, both pin 2 and pin 6 activate the chip to make the output HIGH and LOW "at the same time" but Pin 2 has control over pin 6 and pin 2 makes pin 3 (the output pin) HIGH.



5. The Schmitt Trigger:

Pin 2 detects 33% of rail voltage and pin 6 detects 66%. This gives a gap of 33% between the two. This gap is called the HYSTERESIS GAP.
Here is a circuit to show how the gap works:

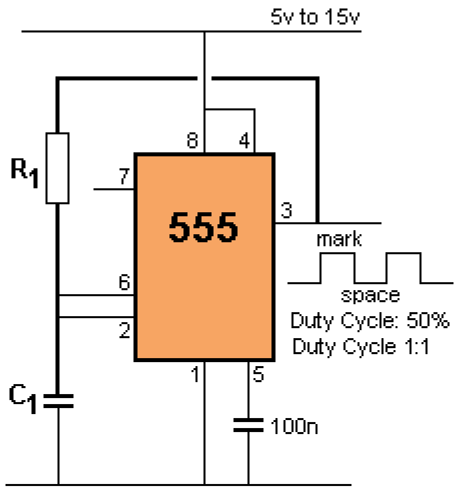


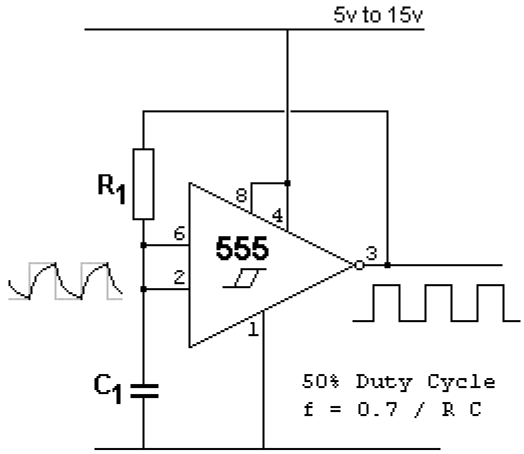
The Hysteresis Gap

The 555 is wired as a SCHMITT TRIGGER. A Schmitt Trigger has a gap between HIGH and LOW input so the signal has to rise and fall a large percentage of rail voltage to make the output change. This means noise on the input will not alter the output as noise has a small amplitude. This type of circuit "cleans up" noisy inputs.
This circuit is also called AN **INVERTER**, A **BUFFER** and AN **AMPLIFIER**

5a. The Schmitt Trigger:

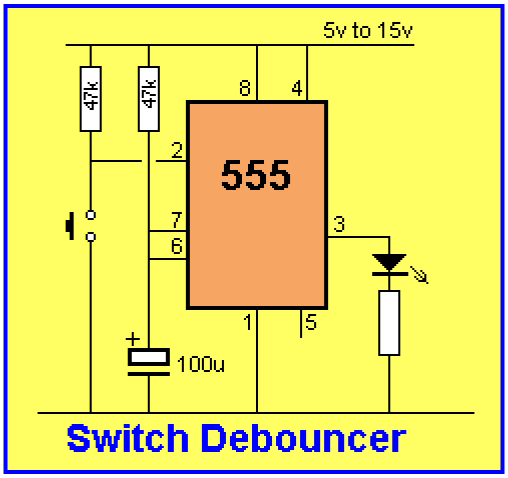
Here is a circuit with the 555 wired as a Schmitt Trigger. It is an oscillator with a square-wave output and operates by detecting 33% and 66% of rail voltage on the capacitor to change the state of the output.
The first diagram shows the rectangular 555 and the second diagram shows it as a triangular shape which is the same shape for a 74c14 (40106) Hex Schmitt Trigger.





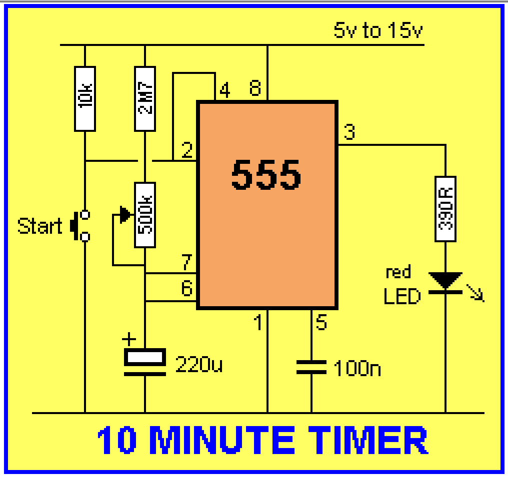
6. One-Shot or Switch Debouncer:

The 555 can take the noisy pulses from a switch and produce a single CLEAN pulse.
The circuit is also called **PULSE EXTENDER**.



7. The 555 as a Delay (Timer):

The 555 can be used as a timer up to 10 minutes. This circuit is also called a DELAY.
To start timing, the START button is pressed briefly and the output of the chip goes LOW. At the expiration of 10 minutes, the output goes HIGH and the red LED illuminates.
A simple application may be for a cooking operation in a shop.
If a product needs to be cooked or heated etc, the button can be pressed and the LED illuminates when the time has expired.



When calculating the time-duration for the circuit above, the capacitor charges from 0v to 2/3 rail voltage.

The timed period:

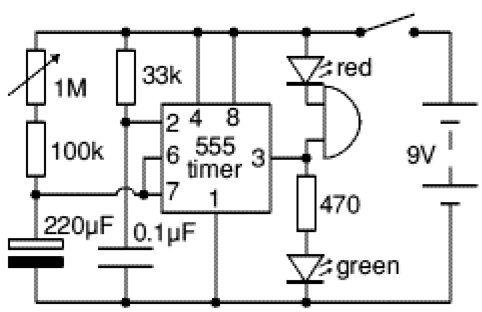
$$T = 1.1 \times R_t \times C_t \text{ seconds}$$

where:

R_t in Ohms

C_t in Farads

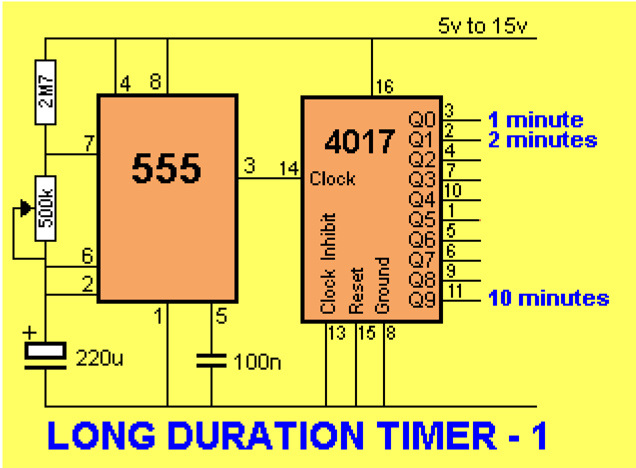
In this circuit we can see pin 2 is taken LOW when the power is applied and quickly goes HIGH. Pin 2 has control over pin 6 as explained in **THE 555 PINS** below.
The action of Pin 2 going LOW "activates the 555" and makes pin 3 HIGH. This only applies because pin 6 is LOW.
Because pin 2 goes HIGH after 0.1secs, it has done its job of turning ON the 555 and now we wait for pin 6 to go HIGH to turn the chip OFF. If pin 2 remained LOW, the chip would NEVER turn OFF.



8. LONG Duration Timer:

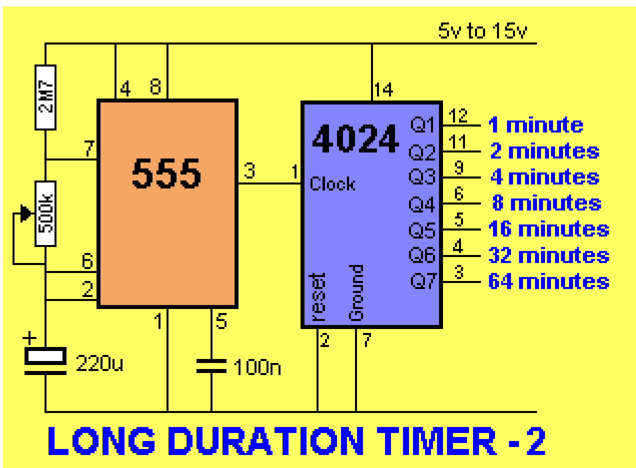
The 555 can be used as a timer up to 10 minutes, but the accuracy of this duration is not reliable and will vary enormously according to the temperature of the day and the leakage of the electrolytic. If you make the time too long, the output may never go HIGH. Reliability stops at about 1 minute, so to get a long duration we connect the 555 to a chip called a "divider-chip" or "counter-chip."
They are called **divider chips** because they are designed to take a high frequency and reduce it to a lower frequency by using a number of flip flops.
A flip-flop has the ability to divide a signal by 2. In other words, the output oscillates at half the input frequency.
If you connect a chain (or train) of flip flops, the signal gets divided by 2, 4, 8, 16, 32, 64, 128 etc.
Thus 1 minute will turn into 2 minutes . . . 128 minutes.
This type of chip is called a BINARY DIVIDER CHIP.
You can also connect a 555 to a divide-by-10 counter (CD4017) to get 2 minutes, 3, 4, 5, 6, 7, 8, 9, 10.
If your timing is 61 seconds, the 10 minutes will be 10 minutes and 10 seconds.

Here are 2 **LONG DURATION** TIMING CIRCUITS:



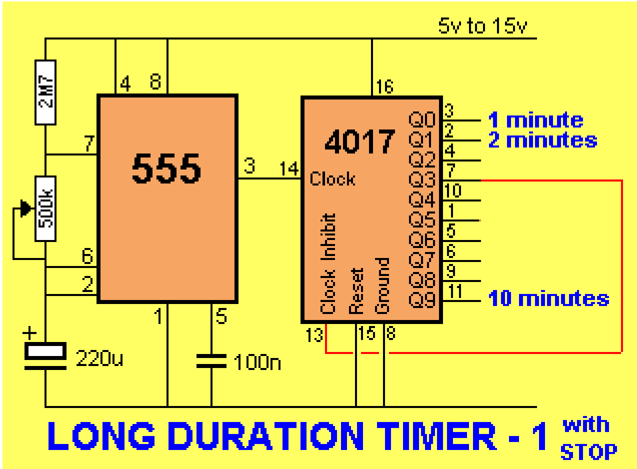
LONG DURATION TIMER -1 will produce a HIGH on pin 3 after 1 minute. Or pin 11 after 10 minutes. The timer start when the power is applied, providing the 220u is fully discharged. If not, the 1st minute will not be accurate. The timer will keep cycling.

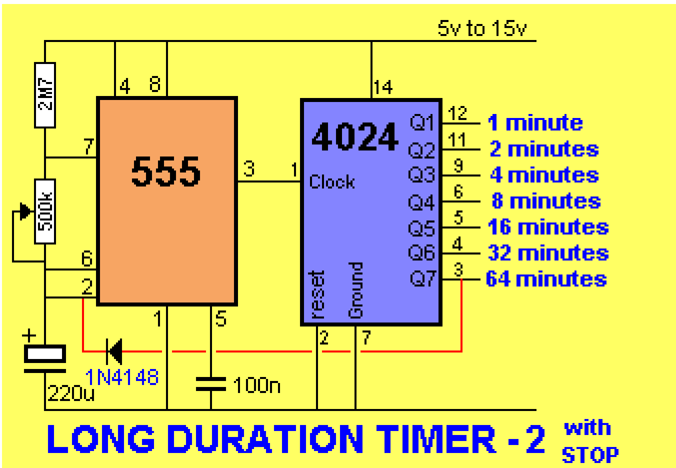
CD 4024 LONG Duration Timer:



You have to test the circuit to see if the counter-chip advances on the HIGH or LOW of the 555 and the actual timing for each pin may be different to the circuit above. The circuit is just a sample of how to connect the two chips.

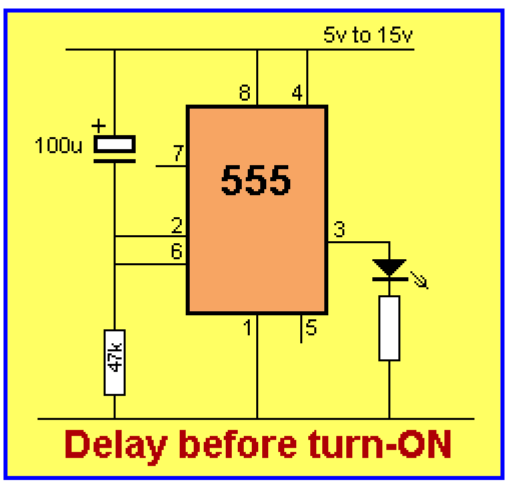
The circuits above will CYCLE. In other words, the outputs will "start all over again" after the longest time-interval has occurred.
To FREEZE the output and make it stay HIGH, you need the following modification:





9. Delay before turn-on:

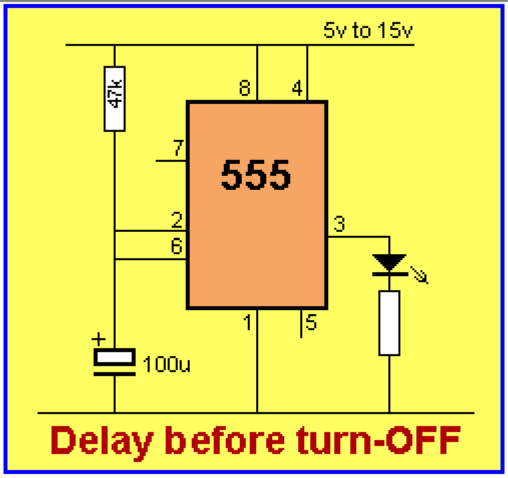
Pin 3 comes on LOW and goes HIGH after a few seconds:



In other words, Pin 2 "turns the chip ON" when it sees a LOW

10. Delay before turn-off:

Pin 3 comes on HIGH and goes LOW after a few seconds:

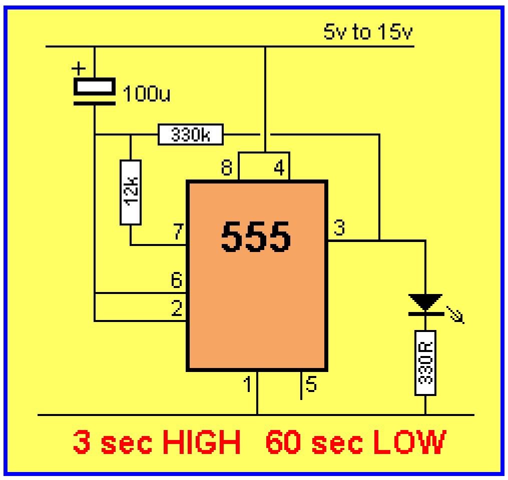


In other words, Pin 6 "turns the chip OFF" when it sees a HIGH

Don't forget, the chip takes 10mA **ALL THE TIME** because it is connected to the supply. **These two circuits show how pins 2 and 6 control the chip.**

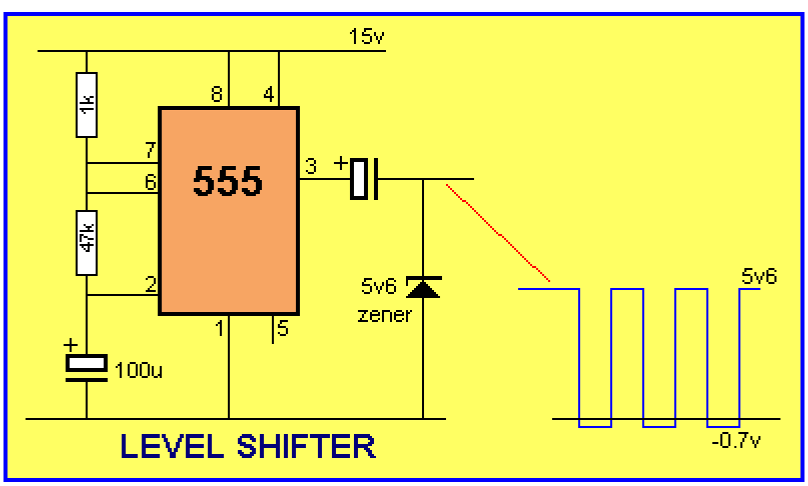
11. HIGH for 3 seconds every 60 seconds

Here's a very simple circuit to create a HIGH for 3 seconds and a LOW for 60 seconds:



12. Level Shifter

This circuit produces a maximum 5.6v on the output and minus 0.7v when the output is LOW. The electro on the output charges to about 8v when the output is HIGH and when it goes low, this 8v would produce a negative 8v on the output, but when the output goes below 0.7v, the zener turns into an ordinary diode and conducts to discharge the electro. This guarantees 0v on the output as pin 3 of the 555 does not go to 0v and sometimes the device being driven by pin 3 does not fully turn off due to this.



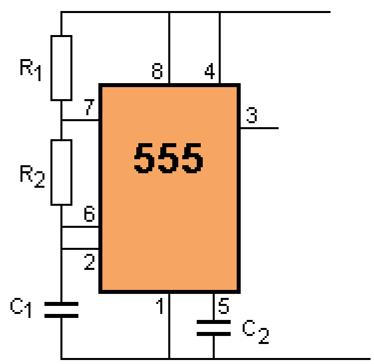
13. PIN 3 - THE OUTPUT PIN

The output of the 555 does not rise to rail voltage or fall to 0v.
The actual value of the HIGH and LOW will depend on the supply voltage and the load on the output. The output can be as much as 2v less than rail voltage and up to 1v above the 0v rail.
Because of the it can fail to turn OFF an NPN transistor connected to the output and it will fail to turn OFF a PNP transistor.

HOW THE 555 WORKS

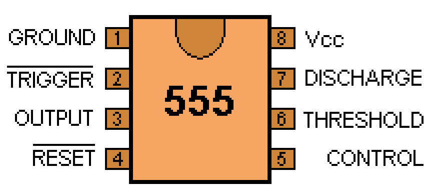
Remember this . . .

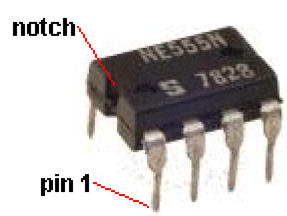
Always draw a 555 with the pins as shown in the diagram.
Pin 3 is output. It pulls HIGH (200mA max). It pulls LOW (200mA max).
Pin 7 is IN PHASE with pin 3. But it only pulls LOW (100mA max). When it is HIGH it is open-circuit - "high-impedance." Pin 7 can be connected to Pin 3 to get 300mA LOW.
Make Pin 2 HIGH. Now Pin 6 detects 66% of rail voltage to make Pin 3 LOW.
If Pins 2 and Pin 6 are connected, chip goes LOW when both pins go HIGH and chip goes HIGH when pins are LOW.
Make Pin 2 LOW. Chip stays HIGH. Pin 6 has NO effect.
Pin 4 is RESET. Must go to 0.8v to reset the chip.



THE 555 PINS

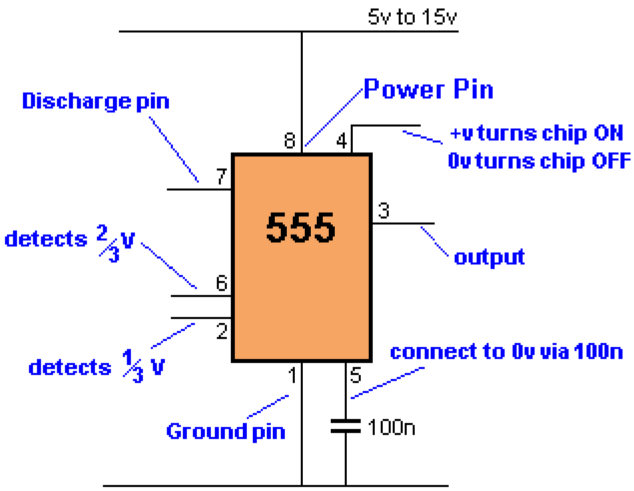
Here is the identification for each pin:





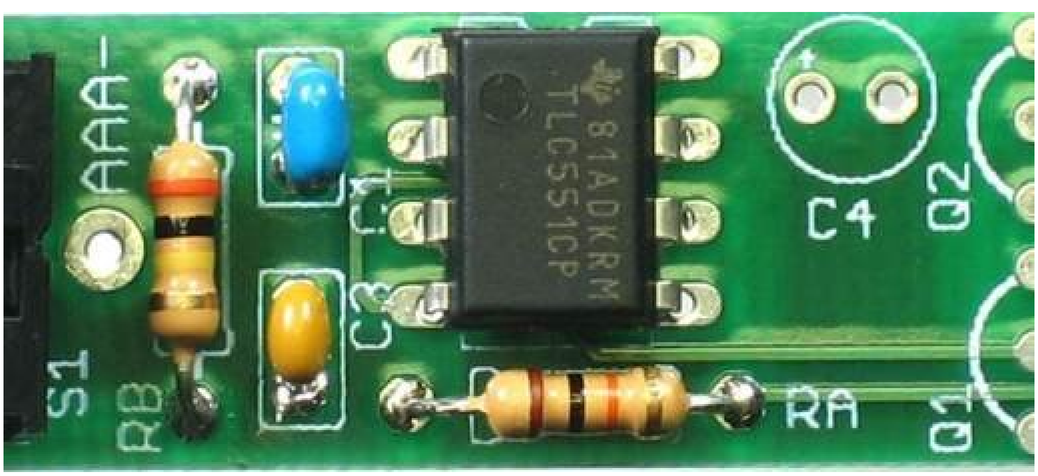
555 PINOUT

When drawing a circuit diagram, always draw the 555 as a building block, as shown below with the pins in the following locations. This will help you instantly recognise the function of each pin:



The Function of each PIN

Pin 1 GROUND. Connects to the 0v rail.
Pin 2 TRIGGER. Detects 1/3 of rail voltage to make output HIGH. Pin 2 has control over pin 6. If pin 2 is LOW, and pin 6 LOW, output goes and stays HIGH. If pin 6 HIGH, and pin 2 goes LOW, output goes LOW while pin 2 LOW. This pin has a very high impedance (about 10M) and will trigger with about 1uA.
Pin 3 OUTPUT. (Pins 3 and 7 are "in phase.") Goes HIGH (about 2v less than rail) and LOW (about 0.5v above 0v rail) and will deliver up to 200mA.
Pin 4 RESET. Maybe internally connected HIGH via 100k in some chips, but NOT others!!. Must be taken below 0.8v to reset the chip.
Pin 5 CONTROL. A voltage applied to this pin will vary the timing of the RC network (quite considerably).
Pin 6 THRESHOLD. Detects 2/3 of rail voltage to make output LOW only if pin 2 is HIGH. This pin has a very high impedance (about 10M) and will trigger with about 1uA.
Pin 7 DISCHARGE. Goes LOW when pin 6 detects 2/3 rail voltage but pin 2 must be HIGH. If pin 2 is HIGH, pin 6 can be HIGH or LOW and pin 7 remains LOW. Goes OPEN (HIGH) and stays HIGH when pin 2 detects 1/3 rail voltage (even as a LOW pulse) when pin 6 is LOW. (Pins 7 and 3 are "in phase.") Pin 7 is equal to pin 3 but pin 7 does not go high - it goes OPEN. But it goes LOW and will sink about 200mA. You can connect pin 7 to pin 3 to get a slightly better SINK capability from the chip.
Pin 8 SUPPLY. Connects to the positive rail.

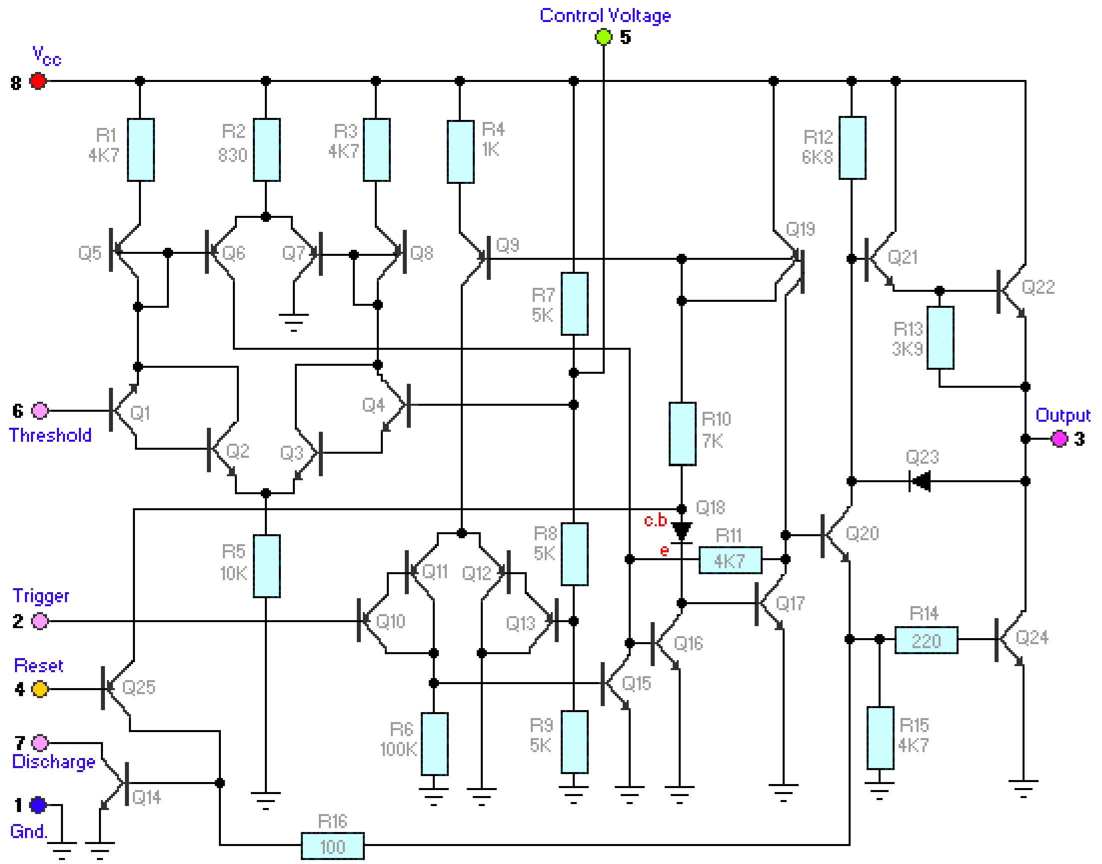


555 in a circuit - note the circle on the chip to identify pin 1
This is sometimes called a "push-out-pin" (hole) to push the chip out of the cavity when it is being moulded and sometimes it has no importance. But in this case it represents pin 1.

SHOOT-THROUGH:

The 555 (the TTL version, such as NE555, SE555) has a problem that both the output transistors turn ON when the output changes from HIGH to LOW or LOW to HIGH. This only occurs for a very short period of time (about 2 nanoseconds) and is called **SHOOT THROUGH**.

This is when a high current flows through a circuit during a part of a cycle. It flows through the collector-emitter junction of transistors Q22 and Q24.
This type of problem may damage a component and it may also put a "blip" (glitch, spike) on the rail voltage.
Since this is generally a very high current, if you have a small filter capacitor (electrolytic) on the rail, the **shoot-through** will take a large amount of energy from the capacitor and extend the width of the time when the voltage is low. The capacitor will take an extra amount of time to recover. This spike may now be wide enough for the rest of the circuit to detect the glitch and create a problem.
That's why you need a large-value electrolytic (100u) across the 555 and try to avoid using it with counting-chips and microcontrollers.

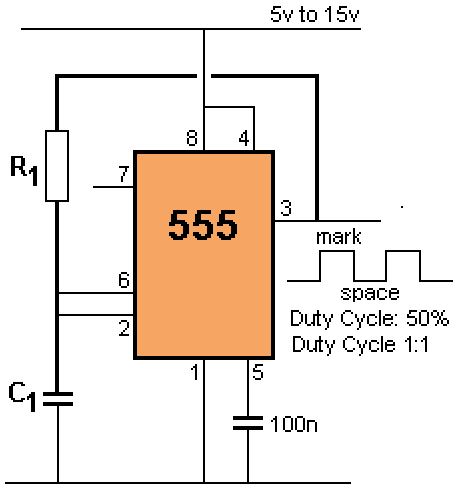


555 Schematic

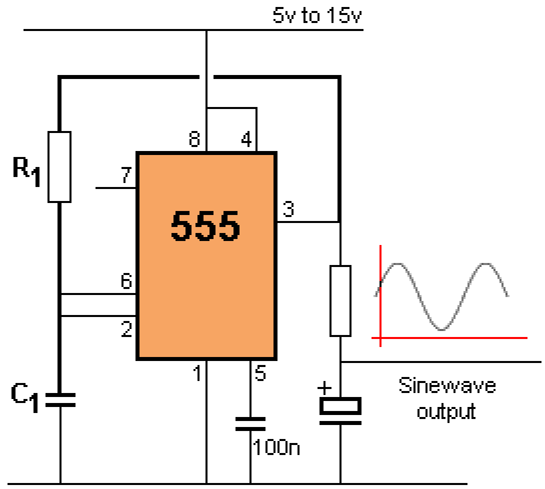
The schematic of the 555 shows the two output transistors can be active when Q20 turns ON and starts to turn on Q24, while Q22 is still turned ON via Q21 and R12. This problem does not affect the operation of the 55, but may affect sensitive IC's in the same project.

THE SIMPLEST 555 OSCILLATOR

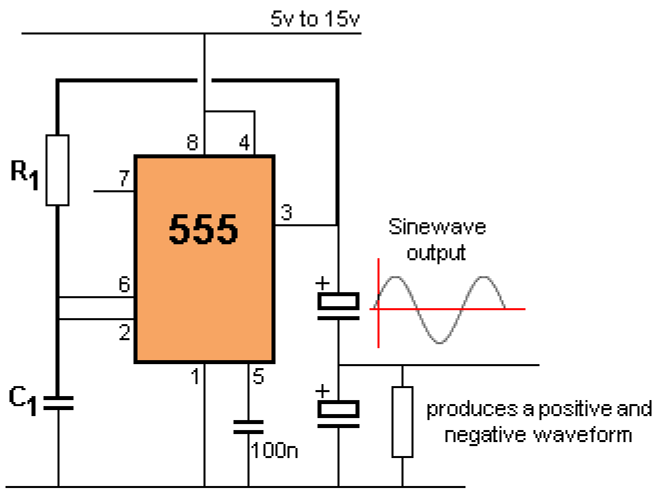
The simplest 555 oscillator takes output pin 3 to capacitor C1 via resistor R1.
When the circuit is turned on, C1 is uncharged and output pin 3 is HIGH. C1 charges via R1 and when Pin 6 detects 2/3 rail voltage, output pin 3 goes LOW. R1 now discharges capacitor C1 and when pin 2 detects 1/3 rail voltage, output pin 3 goes HIGH to repeat the cycle.
The amount of time when the output is HIGH is called the MARK and the time when the output is LOW is called the SPACE.
In the diagram, the mark is the same length as the space and this is called 1:1 or 50%:50%.
If a resistor and capacitor (or electrolytic) is placed on the output, the result is very similar to a sinewave.



SIMPLEST 555 OSCILLATOR



SINEWAVE OUTPUT



SINEWAVE OUTPUT

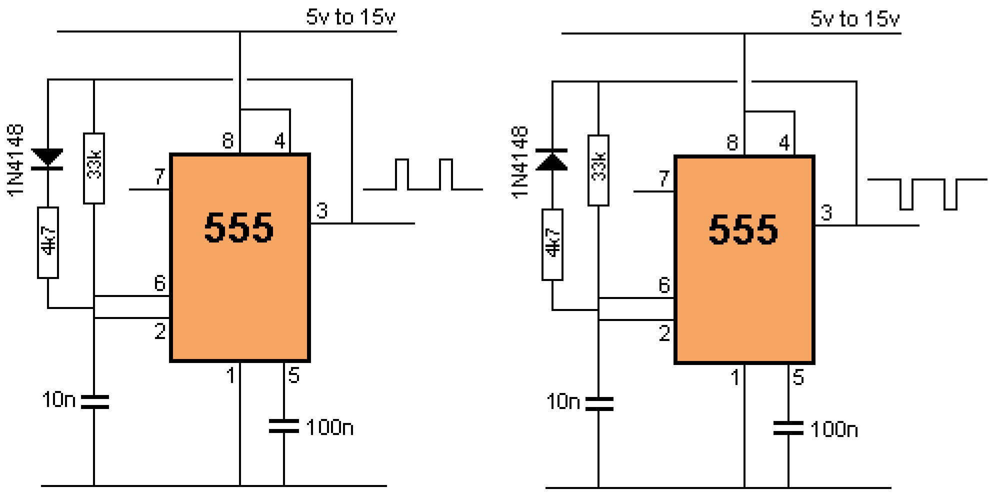
C1 to POSITIVE RAIL

C_1 can be connected to the positive rail. This is not normal practice, however it does work. The output frequency changes when the capacitor is changed from the negative rail to the positive rail. Theoretically the frequency should not change, but it does, and that's why you have to check everything. The frequency of operation in this arrangement is different to connecting the components via pin7 because pin3 does not go to full rail voltage or 0v. This means all the output frequencies are lower than those in the "555 Frequency Calculator." The table shows the frequency for the capacitor connected to the 0v rail and 12v rail:

C_1 to 0v rail			C_1 to 12v rail		
1k	1n	505kHz	1k	1n	255kHz
1k	10n	115kHz	1k	10n	130kHz
1k	100n	23kHz	1k	100n	16kHz
10k	1n	112kHz	10k	1n	128kHz
10k	10n	27kHz	10k	10n	16kHz
10k	100n	3700Hz	10k	100n	1600Hz

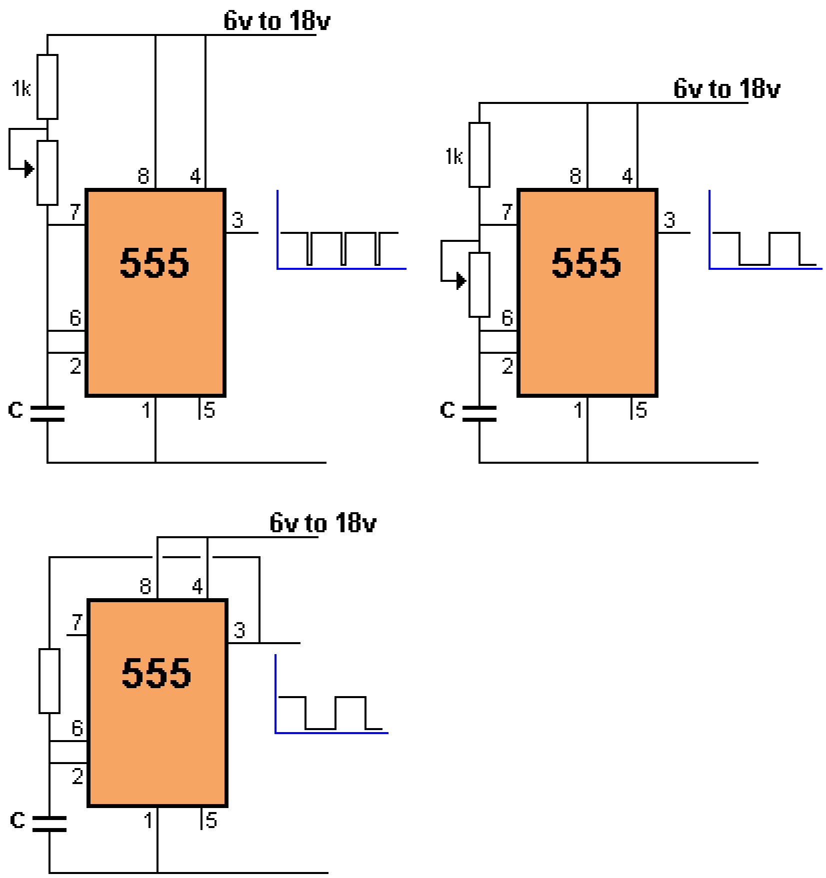
CHANGING THE MARK-SPACE RATIO

This ratio can be altered by adding a diode and resistor as shown in the following diagrams. In the first diagram, the 555 comes ON ("fires-up") with pin 3 low and pin 2 immediately detects this low and makes pin 3 HIGH. The 10n is quickly charged via the diode and 4k7 and this is why the MARK is "short." When the capacitor is 2/3Vcc, pin 6 detects a HIGH and the output of the 555 goes LOW. The 10n is discharged via the 33k and this creates the long-duration SPACE (LOW). The second diagram creates a long-duration HIGH:



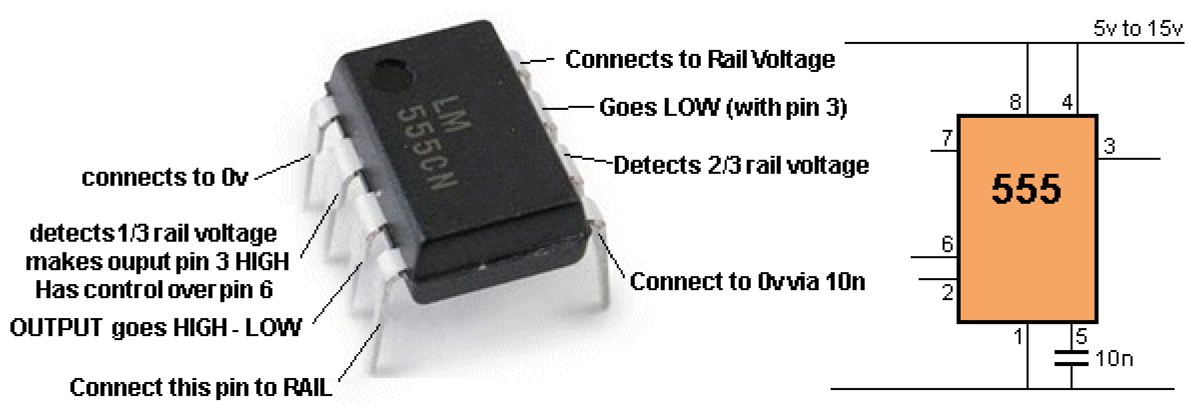
THE THREE BASIC 555 OSCILLATORS

The 3 basic 555 oscillators are shown in these circuits.
The basic points to remember are these:
Pin 7 goes LOW when pin 3 goes LOW.
Pin 6 detects a HIGH
Pin 2 detects a LOW
Pin 3 can be used instead of the supply-rail to deliver a HIGH and instead of pin 7 to deliver a LOW to the timing section made up of pins 2&6 and "C" and a timing resistor.



THE 3 BASIC 555 OSCILLATORS

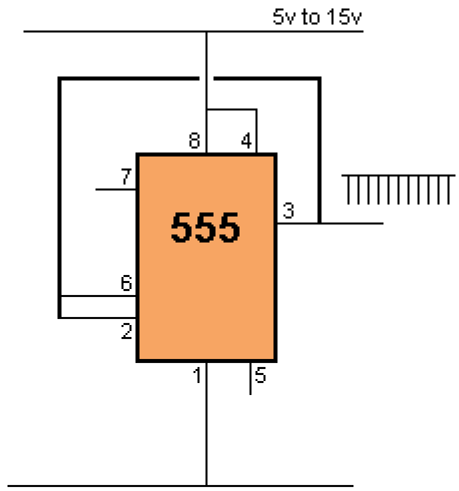
HOW TO REMEMBER THE PINS:



THE 555 PINS AND THEIR FUNCTION

THE FASTEST 555 OSCILLATOR

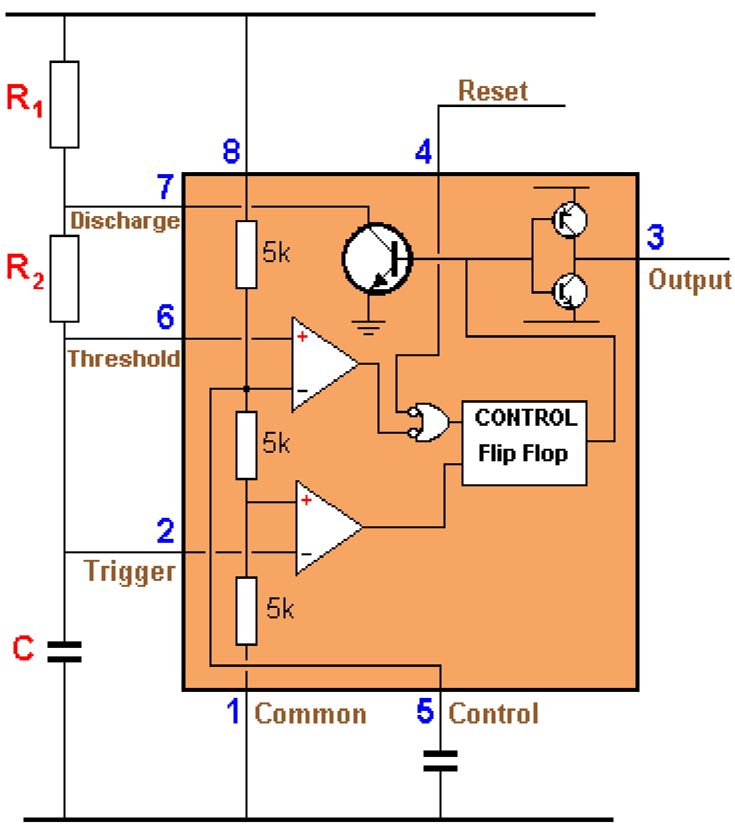
The highest frequency for a 555 can be obtained by connecting the output to pins 2 and 6. This arrangement takes about 5mA and produces an output as shown. The max frequency will depend on the supply voltage, the manufacturer, and the actual type of 555 chip.



FASTEST 555 OSCILLATOR

View the output on a CRO. Our 555 "Test Chip" produced a frequency of 300kHz at 5v and also at 12v. (CMOS versions will operate at a higher frequency.) Note the very short LOW TIME.

INSIDE THE 555



INSIDE THE 555 CHIP

17-3-2014

Note: Pin 7 is "in phase" with output Pin 3 (both are low at the same time).
Pin 7 "shorts" to 0v via a transistor. It is pulled HIGH via R1.
Maximum supply voltage 16v - 18v
Current consumption approx 10mA
Output Current sink @5v = 5 - 50mA   @15v = 50mA
Output Current source @5v = 100mA   @15v = 200mA
Maximum operating frequency 300kHz - 500kHz

Faults with Chip:
Consumes about 10mA when sitting in circuit
Output voltage can be up to 2.5v **less than rail voltage**

Output can be **0.5v to 1.5v above ground**
Sources up to 200mA
Some chips sink only 50mA, some will sink 200mA

A NE555 was tested at 1kHz, 12.75v rail and 39R load.
The Results:
Output voltage 0.5v low, 11.5v high at output current of 180mA
The "test chip" performance was excellent.

HOW TO USE THE 555

There are many ways to use the 555. They can be used in hundreds of different circuits to do all sorts of clever things. They can also be used as three different types of oscillators:

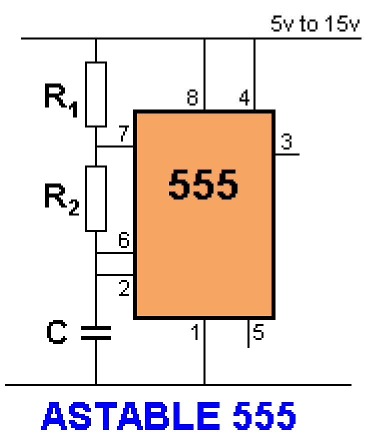
(a) Astable Multivibrator - constantly oscillates

For frequencies above 1 cycle per second, it is called an oscillator (multivibrator or square wave oscillator).
For frequencies below 1 cycle per second it is called a TIMER or DELAY.

(b) Monostable - changes state only once per trigger pulse - also called a ONE SHOT

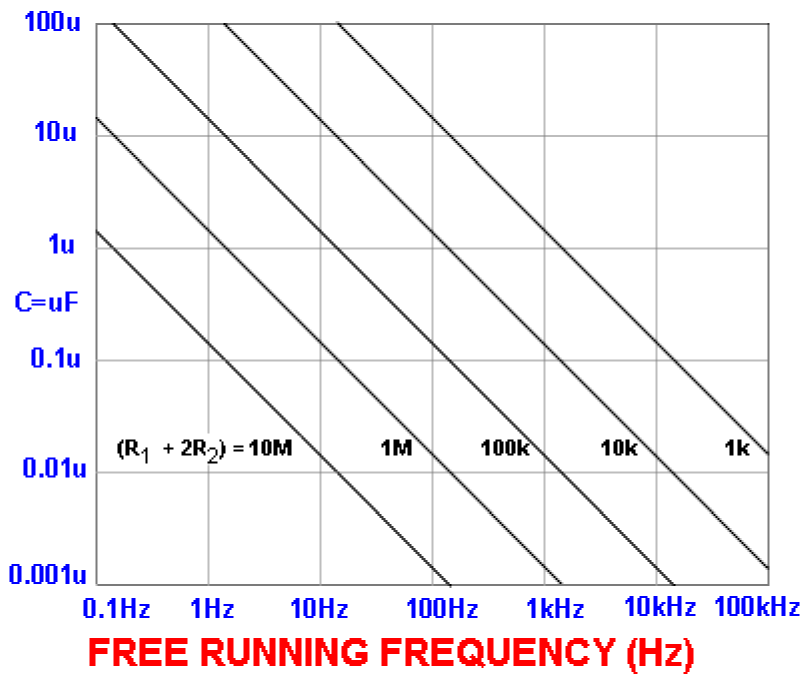
(c) Voltage Controlled Oscillator - called a VCO.

THE ASTABLE (or FREE RUNNING) MULTIVIBRATOR



The capacitor C charges via R1 and R2 and when the voltage on the capacitor reaches 2/3 of the supply, pin 6 detects this and pin 7 connects to 0v. The capacitor discharges through R2 until its voltage is 1/3 of the supply and pin 2 detects this and turns off pin 7 to repeat the cycle.
The top resistor is included to prevent pin 7 being damaged as it shorts to 0v when pin 6 detects 2/3 rail voltage.
Its resistance is small compared to R2 and does not come into the timing of the oscillator.

The following graph applies to the Astable circuit:



Using the graph:

Suppose R1 = 1k, R2 = 10k and C = 0.1u (100n).
Using the formula on the graph, the total resistance = 1 + 10 + 10 = 21k
The scales on the graph are logarithmic so that 21k is approximately near the "1" on the 10k. Draw a line parallel to the lines on the graph and where it crosses the 0.1u line, is the answer. The result is approx 900Hz.

Suppose R1 = 10k, R2 = 100k and C = 1u
Using the formula on the graph, the total resistance = 10 + 100 + 100 = 210k
The scales on the graph are logarithmic so that 210k is approximately near the first "0" on the 100k. Draw a line parallel to the lines on the graph and where it crosses the 1u line, is the answer. The result is approx 9Hz.

The frequency of an astable circuit can also be worked out from the following formula:

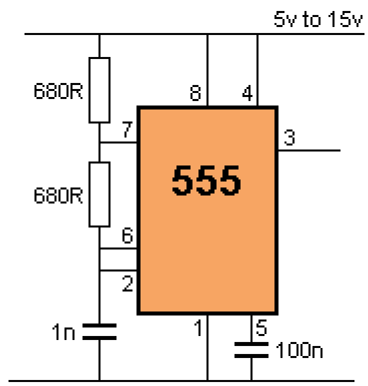
$$\text{frequency} = \frac{1.4}{(R_1 + 2R_2) \times C}$$

555 astable frequencies			
C	R_1 = 1k R_2 = 6k8	R_1 = 10k R_2 = 68k	R_1 = 100k R_2 = 680k
0.001µ	100kHz	10kHz	1kHz
0.01µ	10kHz	1kHz	100Hz
0.1µ	1kHz	100Hz	10Hz
1µ	100Hz	10Hz	1Hz
10µ	10Hz	1Hz	0.1Hz

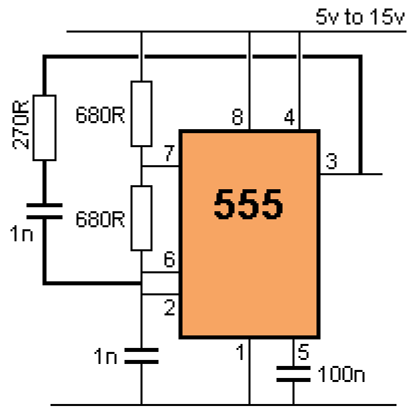
0.001µ	**= 1n**
0.01µ	**= 10n**
0.1µ	**= 100n**

HIGH FREQUENCY OSCILLATORS

360kHz is the absolute maximum as the 555 starts to malfunction with irregular bursts of pulses above this frequency. To improve the performance of the oscillator, a 270R and 1n can be added as shown in the second circuit:

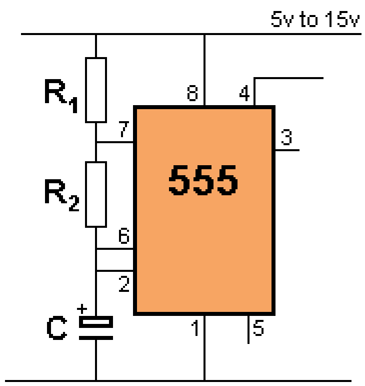


360kHz



360kHz - mods

LOW FREQUENCY OSCILLATORS - called TIMERS

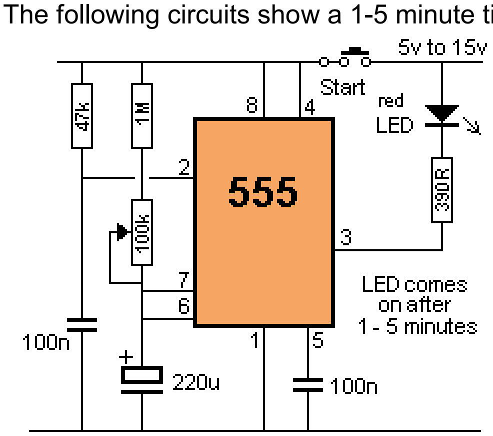


LOW FREQUENCY 555

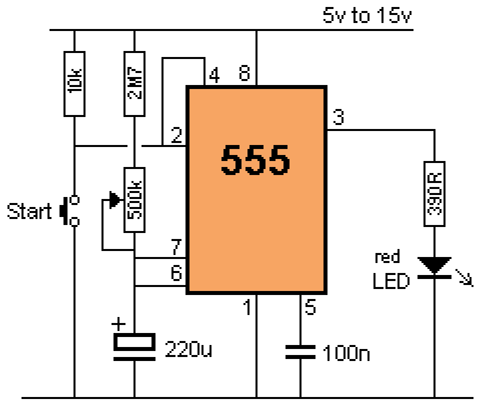
If the capacitor is replaced with an electrolytic, the frequency of oscillation will reduce. When the frequency is less than 1Hz, the oscillator circuit is called a timer or "delay circuit." The 555 will produce delays as long as 30 minutes but with long delays, the timing is not accurate.

555 Delay Times:			
C	R_1 = 100k R_2 = 100k	R_1 = 470k R_2 = 470k	R_1 = 1M R_2 = 1M
10µ	2.2sec	10sec	22sec
100µ	22sec	100sec	220sec
470µ	100sec	500sec	1000sec

The following circuits show a 1-5 minute timer and 10 minute timer:



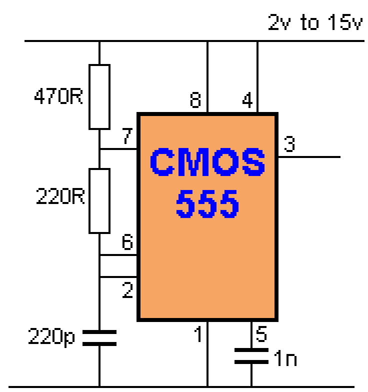
1 - 5 min TIMER



10 MINUTE TIMER

CMOS 555

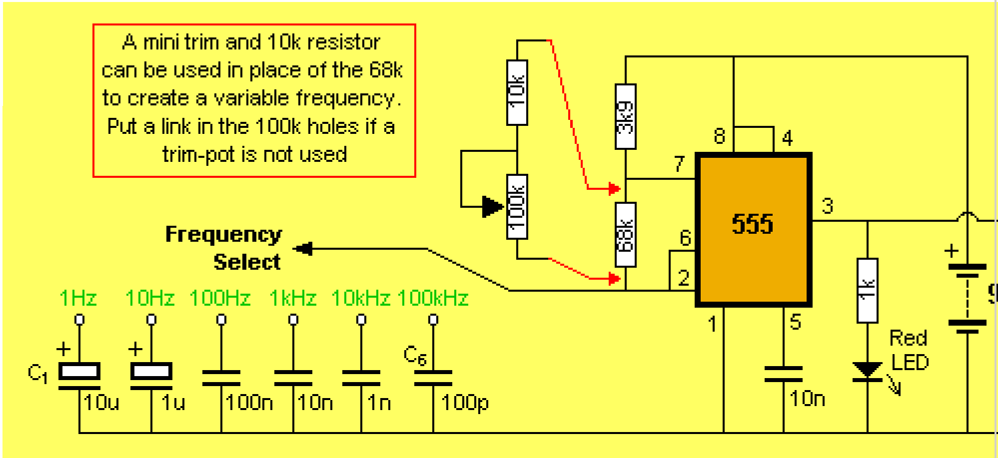
A low power version of the 555 is available from many manufacturers and basically it is a CMOS version of the TTL 555 device.
The CMOS 555 has the same pinouts as the TTL version and can be fitted into the same 8 pin socket but if the circuit needs more current than can be supplied by the CMOS version, it will not produce the same results.
It is the low current capability of the CMOS version that will be the major reason why you cannot directly replace the TTL version with the CMOS version.
It will operate from 1v (only some manufacturers) to 15v and will work up to 3MHz in astable mode.
Current consumption @5v is about 250uA (1/4mA)
But the major thing to remember is the output current capability.
At 2v, the chip will only deliver 0.25mA and sink only 1mA.
At 5v, the chip will deliver 2mA and sink only 8mA
At 12v the chip will deliver 10mA and sink 50mA
At 15v the chip will deliver 100mA and sink 100mA



CMOS 555
MAXIMUM FREQUENCY

SQUARE WAVE OSCILLATOR KIT:

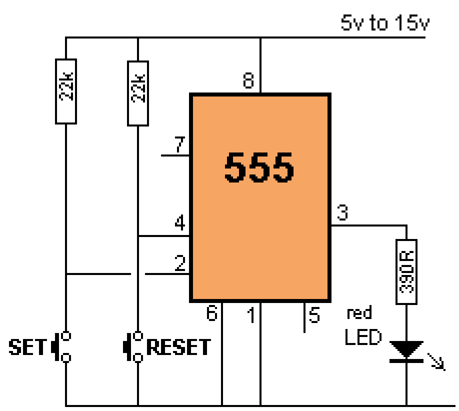
BUY NOW



A square wave oscillator kit can be purchased from Talking Electronics for approx $10.00
See website: **Square Wave Oscillator**
It has adjustable (and settable) frequencies from 1Hz to 100kHz and is an ideal piece of Test Equipment.
(This link will send an email to Colin Mitchell and you will be advised of costs and how to send money via Paypal or credit card.)

Bi-stable or "Latch" or "2-state" 555

The bi-stable 555 has two steady states. SET turns ON the LED and RESET turns the LED off. The 555 comes on in reset mode as Pin2 does not see a LOW to SET the 555.
See also: **Divide By Two**



BI-STABLE 555

Monostable or "One Shot" or Pulse Extender

When the circuit is turned on, the output is LOW and a brief negative pulse on pin 2 will make the output go HIGH for a period of time determined by the value of R and C. If pin 2 is low for longer than this period, the output will remain HIGH while pin 2 is LOW and immediately go LOW when pin 2 goes HIGH.

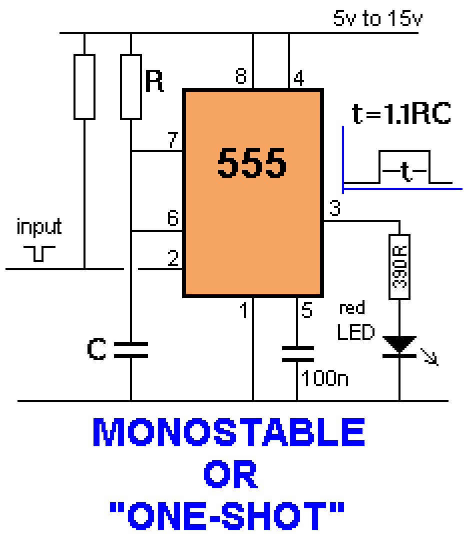
CIRCUIT OPERATION
When the circuit is turned on, the capacitor is uncharged. Pin 6 sees a LOW and pin 2 sees a HIGH.
Remember: Pin 2 must be LOW to make the output HIGH.
Pin 6 must be HIGH to make the output LOW.

Neither pin is "controlling the chip" at start-up.

SET OR RESET?

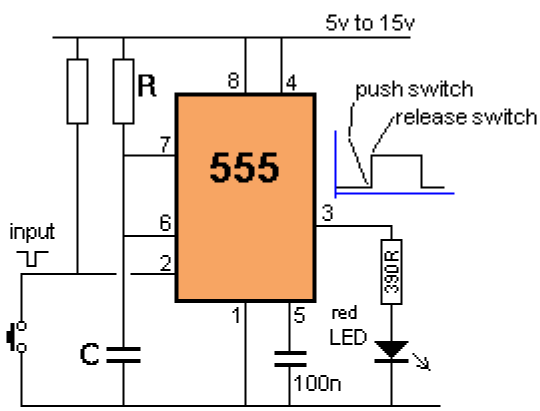
The 555 contains a FLIP-FLOP and the output can be either HIGH or LOW if the voltage on pins 2 and 6 are not at the correct levels.
If pin 6 is HIGH and pin 2 is LOW - the output will be HIGH - pin 2 is sending a "set" message
If pin 6 is HIGH and pin 2 is HIGH - the output will be LOW - pin 6 is sending a "reset" message
If pin 6 is LOW and pin 2 is LOW - the output will be HIGH - pin 2 is sending a "set" message
If pin 6 is LOW and pin 2 is HIGH - the output will be HIGH or LOW - because no pin is sending a "set" or "reset" message.

When pin 2 see a LOW pulse, the chip goes to SET mode and the output goes HIGH. Pin 7 goes OPEN and capacitor C charges via R. When pin 6 sees 2/3 rail voltage, the chip goes to RESET mode with pin 3 and 7 LOW. The capacitor instantly discharges via pin 7 and the circuit waits for a negative pulse on pin 2.

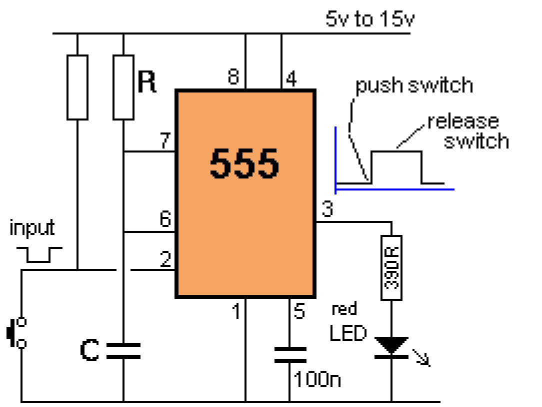


Re-triggerable 555

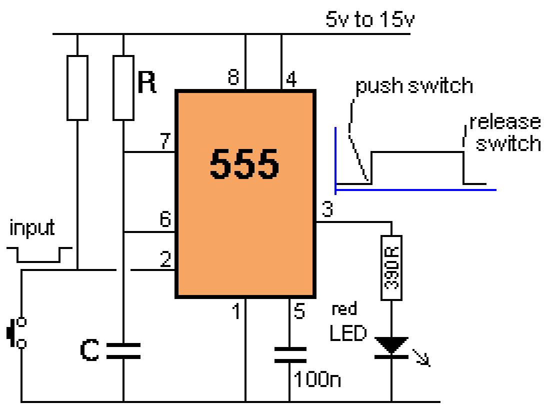
In the previous circuit, the output is LOW until pin 2 sees a brief LOW. The output goes HIGH and remains HIGH until pin 6 sees a HIGH via the charging of the capacitor. In other words the 555 extends the pulse according to the value of **R** and **C.**
The following diagrams show the output when the switch is pressed immediately, at half-time at the end of time and after the time has expired:



The switch is pushed and released quickly in the circuit above. Note the HIGH time for the output.

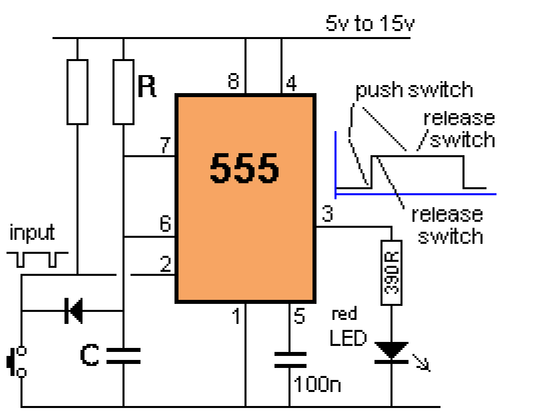


The switch is pushed and released slowly in the circuit above. Note the HIGH time for the output is the same as before.



The switch is pushed and released just when the time is expiring. Note the HIGH time for the output is the same as before. The switch does not extend (re-trigger) the 555.

To re-trigger the 555, the **capacitor** must be discharged. To do this we add a diode as shown so the capacitor discharges each time the switch is pressed:

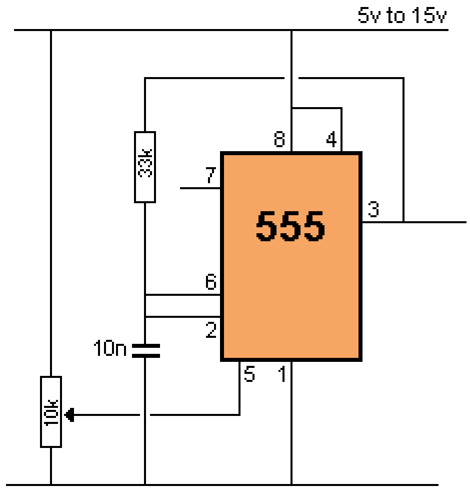


Re-triggering the 555

THE 555 AS A VOLTAGE

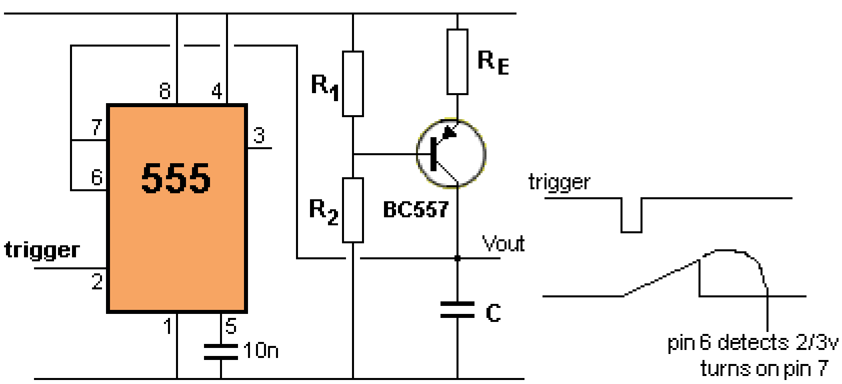
CONTROLLED OSCILLATOR (VCO)

By adjusting the voltage on pin 5, (the CONTROL pin) the frequency of the oscillator can be adjusted quite considerably. See Police Siren for an application.



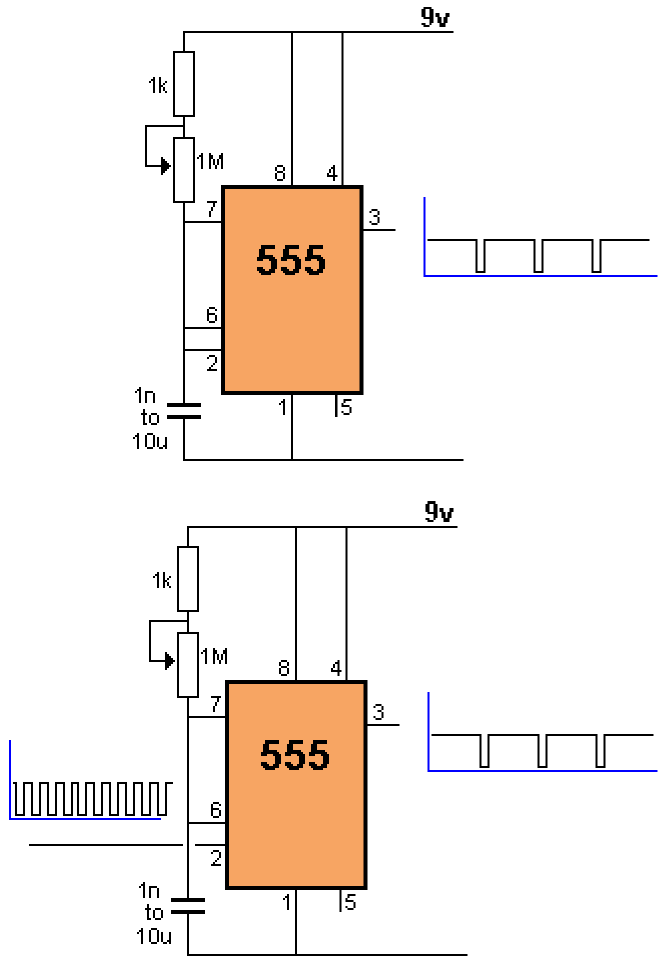
THE 555 AS A RAMP GENERATOR

When a capacitor is charged via a constant current, the waveform across it is a ramp.



FREQUENCY DIVIDER

A 555 can be used to divide a frequency by almost any division.
It works this way:
A 555 is set-up to produce the required output frequency.
Pin 2 is then taken to the input frequency and this turns the 555 into a Monostable Multivibrator.
The circuit will detect a LOW on pin 2 to start the timing cycle and pin 3 will go HIGH. The 555 will not respond to any more pulses on pin 2 until pin 6 detects a HIGH via the charging of the capacitor. The value of C and the 1M pot need to be adjusted to produce the desired results.

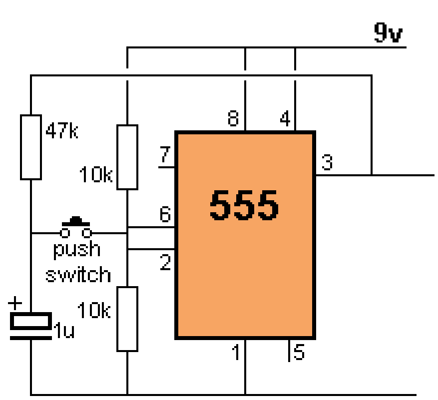


FREQUENCY DIVIDER

DIVIDE BY 2

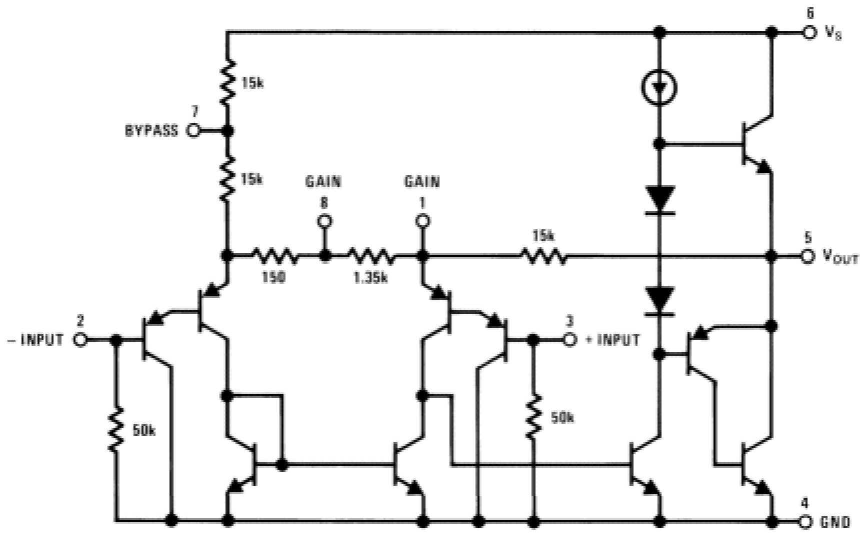
A 555 can be used to divide-by-2
When pins 2 and 6 are connected, they detect 1/3 and 2/3 of rail voltage.
When the detected voltage is below 1/3, the output goes HIGH and when the voltage is above 2/3, the output goes LOW.
The push switch detects the output voltage and after a short period of time the electrolytic will charge or discharge and it will be HIGH or LOW.
If the switch is pressed for a short period of time, the output will change. If the switch is kept pressed, the output will oscillate at a low frequency.

This circuit can also be used as a Push-ON Push-OFF.

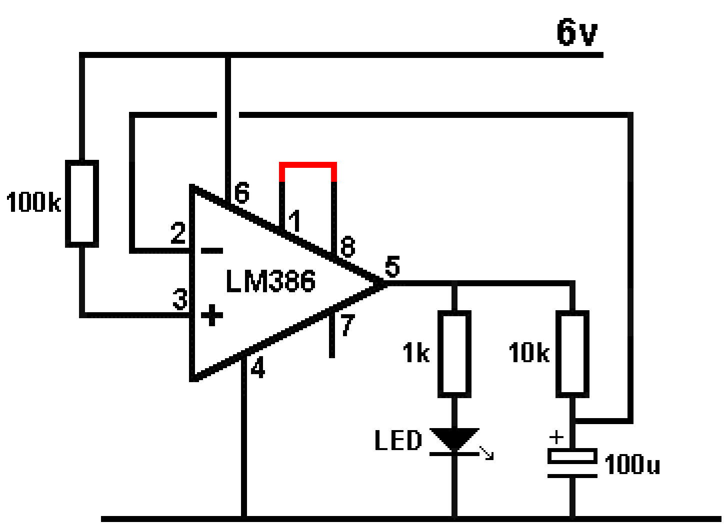


LM386 LED FLASHER

If you don't have a 555, you can use an LM386 IC to flash a LED. This will show how an LM386 chip works and and how to use chips for purposes other than their normal intent.
An LM386 IC is an 8-pin 250mW power amplifier with a differential input, similar to an op-amp.
Here is the internal circuit:



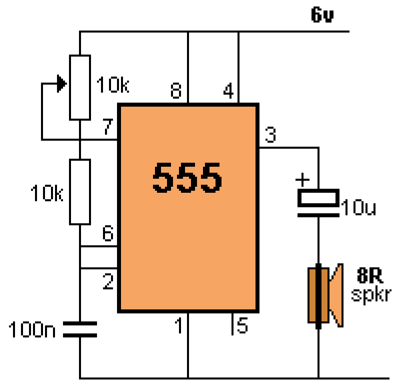
Normally pin 3 has zero volts on it, but the 100k puts about 35% of rail voltage on the pin.
This means pin 3 has an input impedance of about 300k.
The actual voltage does not matter, as long as it is slightly higher than zero volts, so pin 2 can have an effect when it goes lower than pin 3.
When the circuit is turned on, the 100u is uncharged and zero volts is applied to pin 2.
This means pin 2 is lower than pin 3 and the output goes HIGH to illuminate the LED.
The 100u charges via the 10k and after a short period of time the voltage on pin 2 is higher than pin 3 and it makes the output go LOW. The LED turns OFF and the 100u starts to discharge via the 10k to repeat the cycle.
The chips has a gain of 20, but this is not enough for this circuit to flash a LED. By joining pins 1 and 8, the gain is increased to 200 or more and the circuit works successfully.



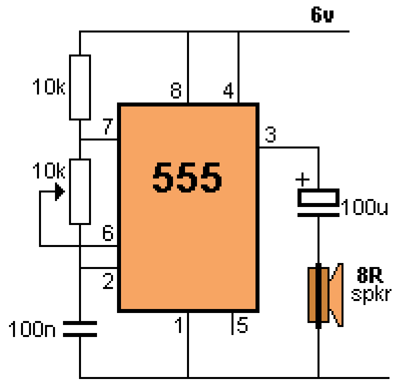
LED FLASHER USING LM386 IC

"No-No's"

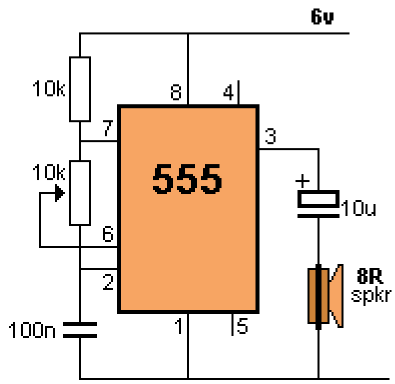
Here are some mistakes to avoid:
1. Pin 7 gets connected to the 0v rail via a transistor inside the chip during part of the operation of the 555. If the pot is turned to very low resistance in the following circuit, a high current will flow through the pot and it will be damaged:



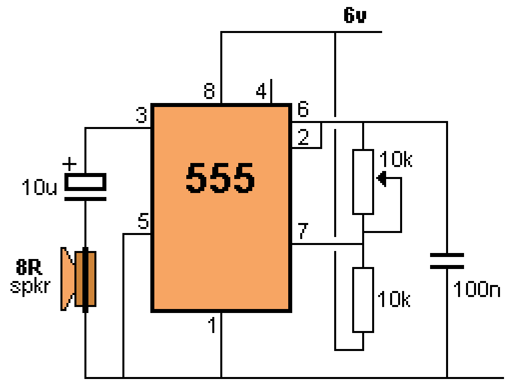
2. The impedance of the 100u electrolytic will allow a very high current to flow and the chip will get very hot.   Use 10u maximum when using 8R speaker. (The temp of the chip will depend on the frequency of the circuit.)



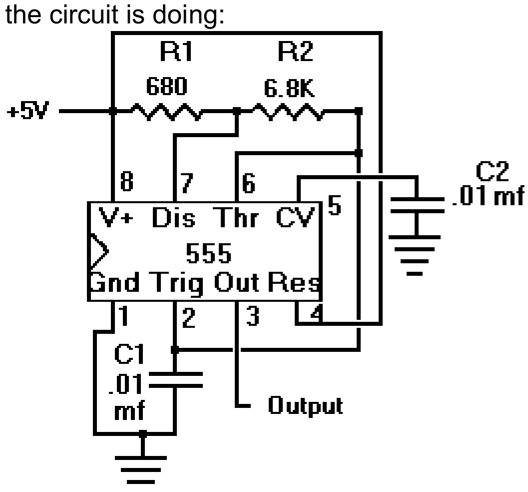
3. The reset pin (pin 4) is internally tied HIGH via approx 100k but it should not be left floating as stray pulses may reset the chip.



4. Do not draw 555 circuits as shown in the following diagram. Keep to a standard layout so the circuit is easy to follow.

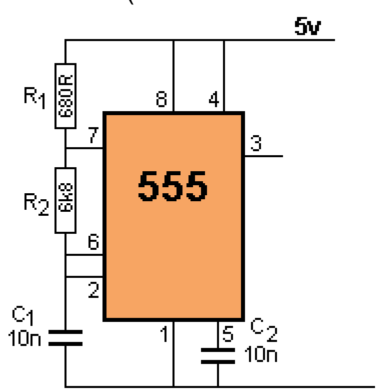


5. Here's an example from the web. It takes a lot of time to work out what the circuit is doing:

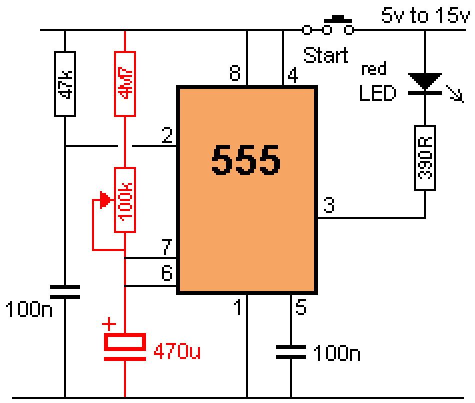


The aim it to lay-out a circuit so that it shows instantly what is happening. That's why everything must be in recognised locations.

Here is the corrected circuit: From this diagram it is obvious the circuit is an oscillator (and not a one-shot etc).

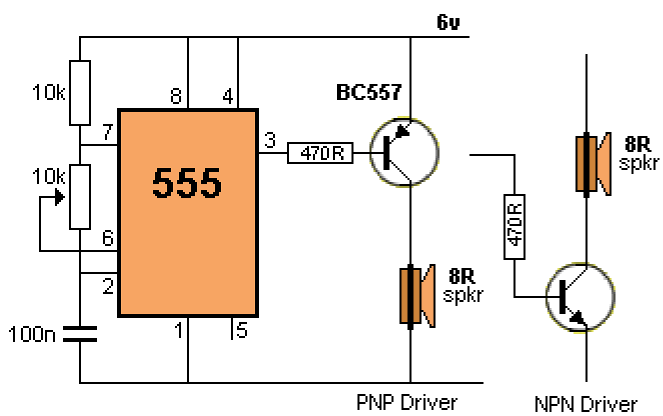


6. Don't use high value electrolytics and high resistances to produce long delays. The 555 is very unreliable with timing values above 5-10 minutes. The reason is simple. The charging current for the electrolytic is between 1 - 3 microamp in the following diagram (when the electro is beginning to charge) and drops to less than 1 microamp when the electro is nearly charged.
If the leakage of the electro is 1 microamp, it will never fully charge and the 555 will never "time-out."

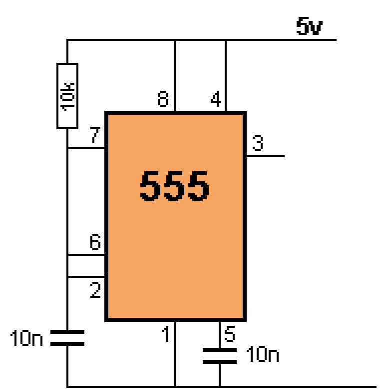


15 min TIMER

7. Do not connect a PNP to the output of a 555 as shown in the following diagram. Pin 3 does not rise high enough to turn the transistor OFF and the current taken by the circuit will be excessive. Use an NPN driver.



8. Do not connect pin 7 directly to the capacitor. Pin 7 connects to the 0v rail during part of a cycle and this will discharge the capacitor very quickly and produce a very brief "low" on the output.
This may upset the clocking of a chip (such as a CD4017).
Use a resistor of at least 1k to increase the width of the LOW.



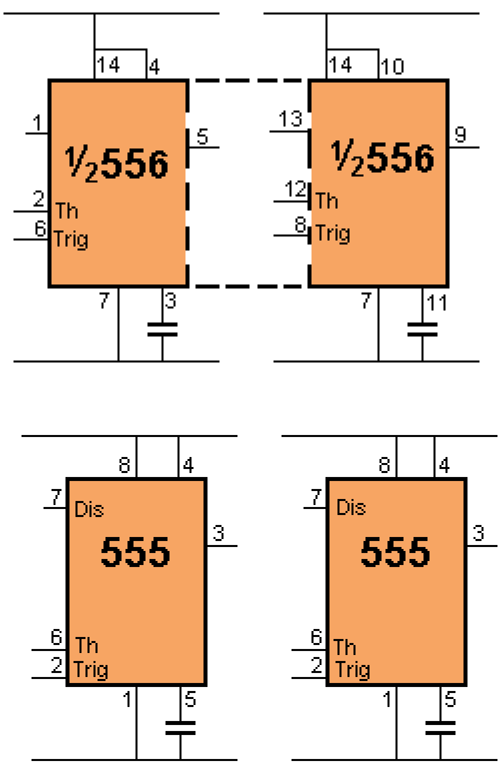
555's

Here is a list of 555's from different manufacturers plus the range of low voltage, low current 555's. The normal 555 is called a TTL or Transistor-Transistor-Logic chip and it consumes about 10mA when "sitting and doing nothing." It will work from 4v to 18v.
A low current version is available from the list below, (called a CMOS version) and consumes about 10uA to 100uA. Some of these chips work from 1.5v to 15v (ZSCT1555 = 9v max) but they can sink and source only about 100mA (less than 30mA at 2v).
The 555 is the cheapest and the others cost about double.
The normal 555 oscillates up to 300kHz. A CMOS version can oscillate to 3MHz.
You need to know the limitations as well as the advantages of these chips before substituting them for the normal 555:

Manufacturer	Model	Remark
Custom Silicon Solutions	CSS555/CSS555C	CMOS from 1.2V, IDD < 5uA
ECG Philips	ECG955M	
Exar	XR-555	
Fairchild Semiconductor	NE555/KA555	
Harris	HA555	
IK Semicon	ILC555	CMOS from 2V
Intersil	SE555/NE555/ICM7555	
Lithic Systems	LC555	
Maxim	ICM7555	CMOS from 2V
Motorola	MC1455/MC1555	
National Semiconductor	LM1455/LM555/LM555C	
National Semiconductor	LMC555	CMOS from 1.5V
NTE Sylvania	NTE955M	
Raytheon	RM555/RC555	
RCA	CA555/CA555C	
STMicroelectronics	NE555N/ K3T647	
Talking Electronics	TE555-1, -2, -3, -4	email **Talking Electronics** $2.50 ea
Texas Instruments	SN52555/SN72555; TLC555	CMOS from 2V
Zetex	ZSCT1555	down to 0.9V (9v max)

REPLACING A 556 WITH TWO 555's

Here is a handy reference to replace a 556 dual timer with two 555's:



The table shows the pin numbering for each timer:

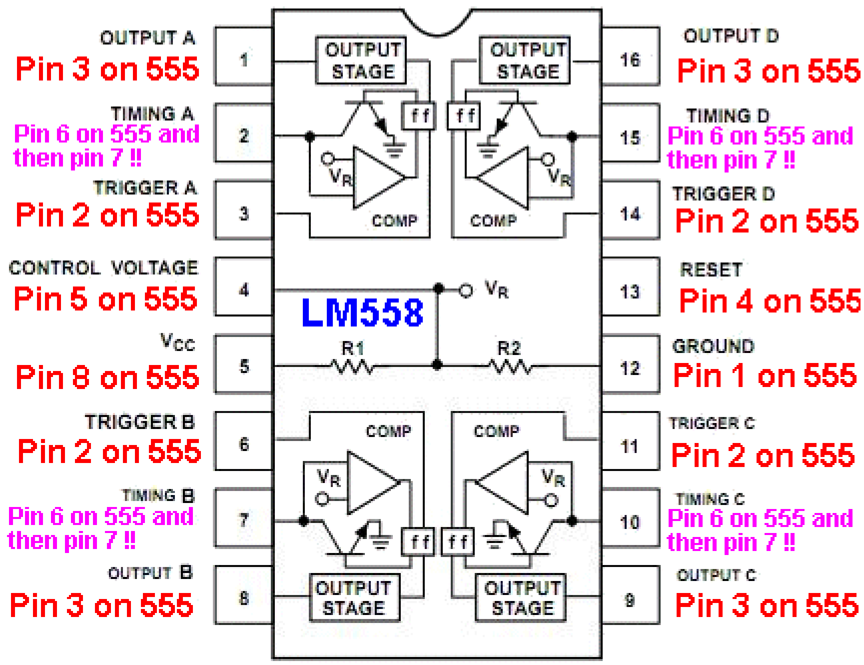
	555	556 - Timer 1	556 - Timer 2
Ground (–)	1	7	7
Trigger	2	6	8

Output	3	5	9
Reset	4	4	10
Control	5	3	11
Threshold	6	2	12
Discharge	7	1	13
Vcc (+)	8	14	14

REPLACING A 558 WITH FOUR 555's

This is an obsolete chip. No-one stocks it.
The LM558 only has 100mA output current (the LM555 has up to 200mA).
The output only goes LOW. In other words, the output only SINKS.

I suggest only using 555's in all projects. You can easily remember the pin numbering on a 555 and this makes servicing and testing and fault-finding easy. A circuit using a "558" (NE55, LM558) can be converted to using 4 x LM555's by referring to the following image:



The NE558 is a very messy chip and it seems the pin that is equivalent to pin 6, changes to pin 7 to discharge the capacitor when 66% of rail voltage is reached.

SUBSTITUTING A 555 - part 1

Although a 555 is a wonderful chip, it may not be the best choice for some applications.
You may require an oscillator frequency higher than 1MHz, or a very low quiescent current. You may also need 4 or more 555's to get the timing and delays you require.
Here are some circuits to help you substitute a 555.

The 74c14 IC contains 6 Schmitt Trigger gates and each gate can be used to replace a 555 in SOME circuits. The voltage for a 74c14 is 3v to 15v. Maximum output current per gate is 15mA. Max frequency of operation: 2MHz - 5MHz.
Quiescent current is 1uA if all inputs are 0v or rail voltage.

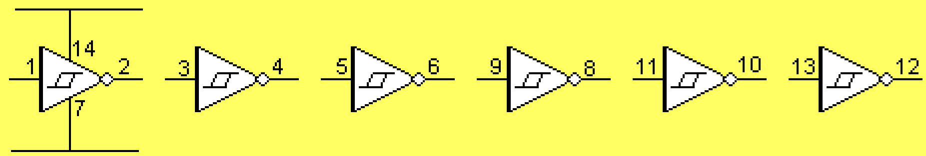
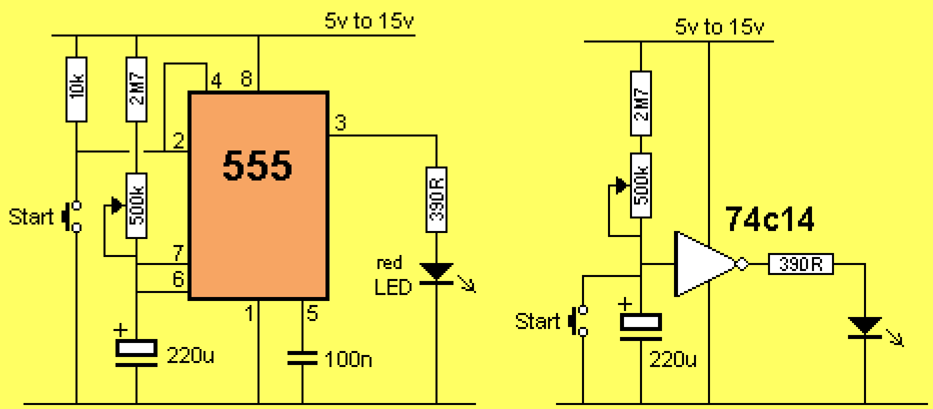
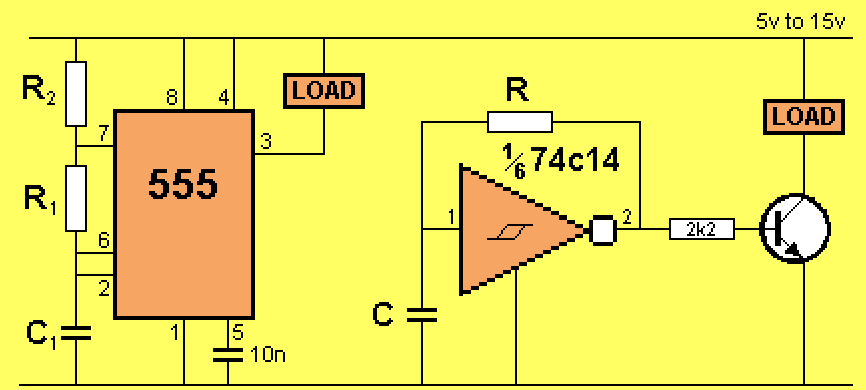


Fig: 8 The six Schmitt Trigger Gates for a 74c14 IC



10 MINUTE TIMER



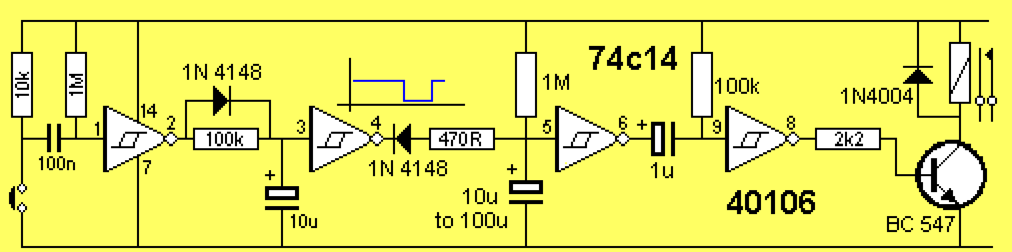
THE 555 OSCILLATOR AND ITS EQUIVALENT SCHMITT

SUBSTITUTING A 555 - part 2

If you need a special function or special effect, it may take 2, 3 or more 555's to do the job. The 74c14 has 6 gates and can create 6 "building blocks."
Here are some circuits to show its versatility:

2 MINUTE TIMER

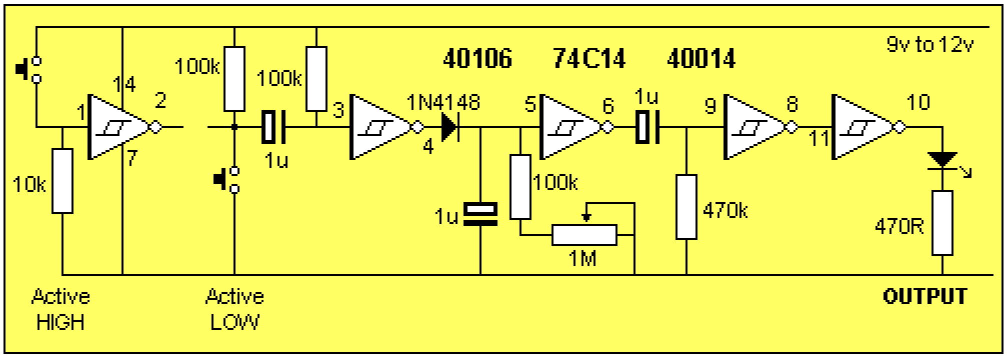
The relay is energized for a short time, 2 minutes after the push-button is pressed. The push-button produces a brief LOW on pin 1, no matter how long it is pushed and this produces a pulse of constant length via the three components between pin 2 and 3. This pulse is long enough to fully discharge the 100u timing electrolytic on pin 5.
The 100k and electrolytic between pins 6 and 9 are designed to produce a brief pulse to energize the relay.



Produces a short pulse after 2 minutes

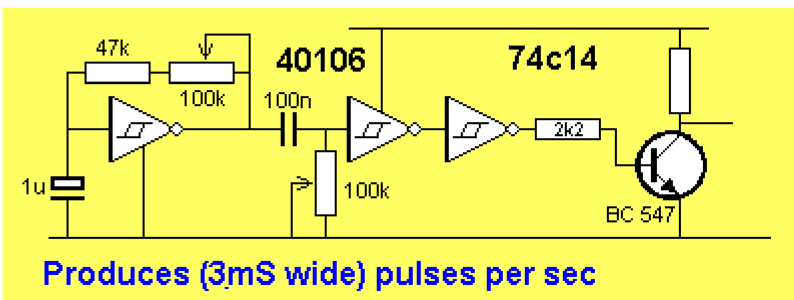
OUTPUT AFTER 2 MINUTES

Here is another very similar circuit. Use either the active HIGH or Active LOW switch and if the Active LOW switch is used, do not connect the parts or gate between pins 1 and 2 to the rest of the circuit.



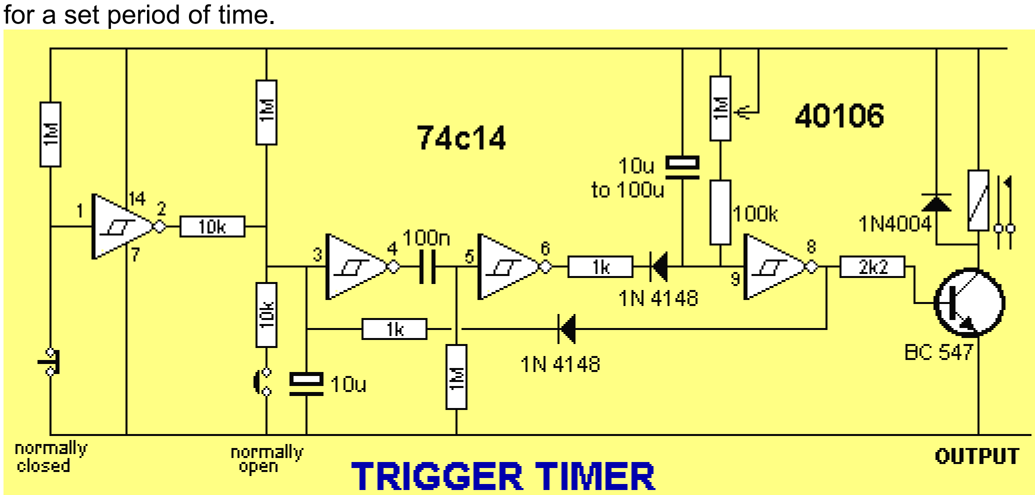
PULSER

The 74c14 can be used for lots of different circuits. In the following design, the output produces 3mS pulses every second. The circuit is adjustable to a wide range of requirements.



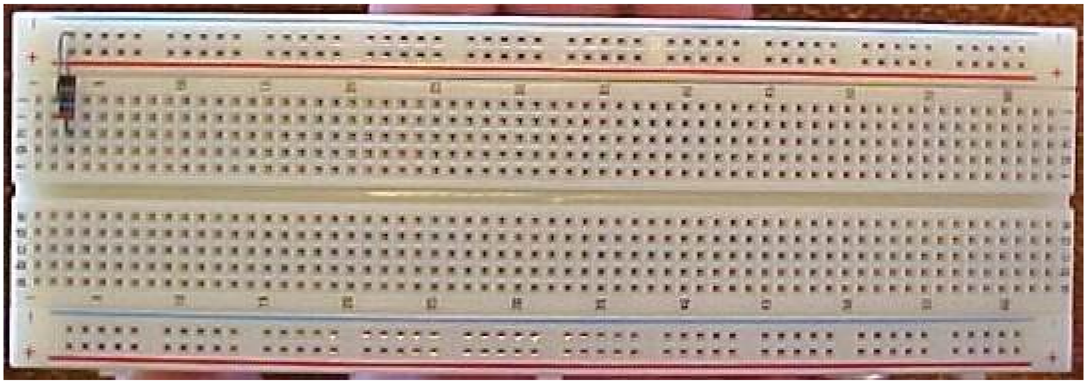
TRIGGER TIMER

The next design interfaces a "Normally Open" and "Normally Closed" switch to a delay circuit.
The feedback diode from the output prevents the inputs re-triggering the timer (during the delay period) so that a device such as a motor, globe or voice chip can be activated for a set period of time.

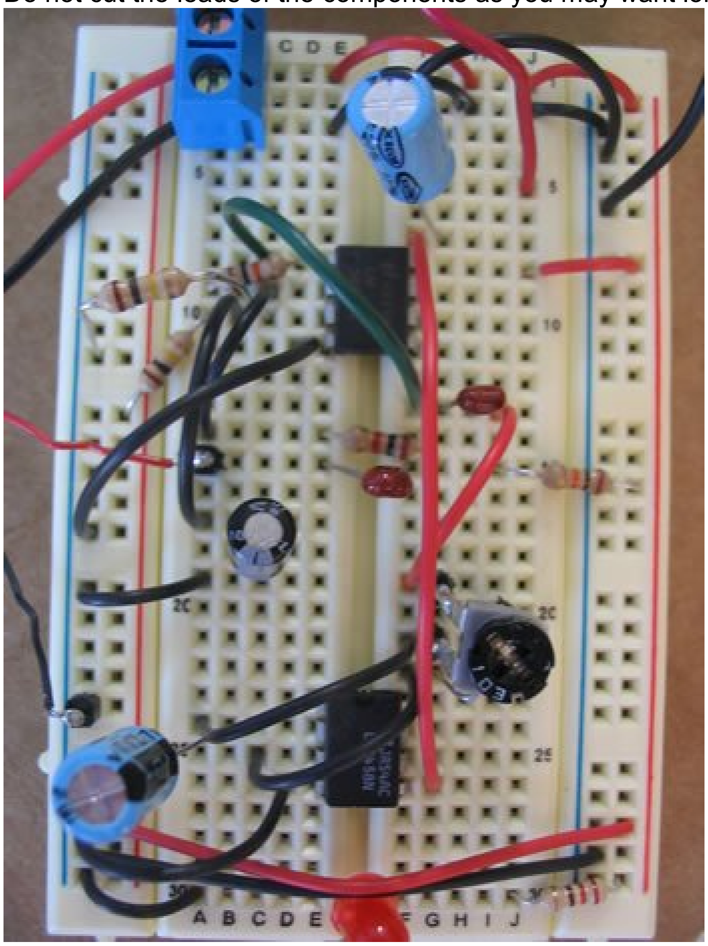


BUILDING THE CIRCUITS

The fastest way to put a circuit together is on BREADBOARD. The cheapest and best bread-board has power-rails and sets of "tie-points" or "holes" as shown in this photo:



Connect the components with hook-up wire (called jumpers) by stripping the ends to expose the wire at both ends. Or you can use 0.5mm tinned copper wire (make sure the jumpers do not touch each other).
Do not cut the leads of the components as you may want long leads on another project.

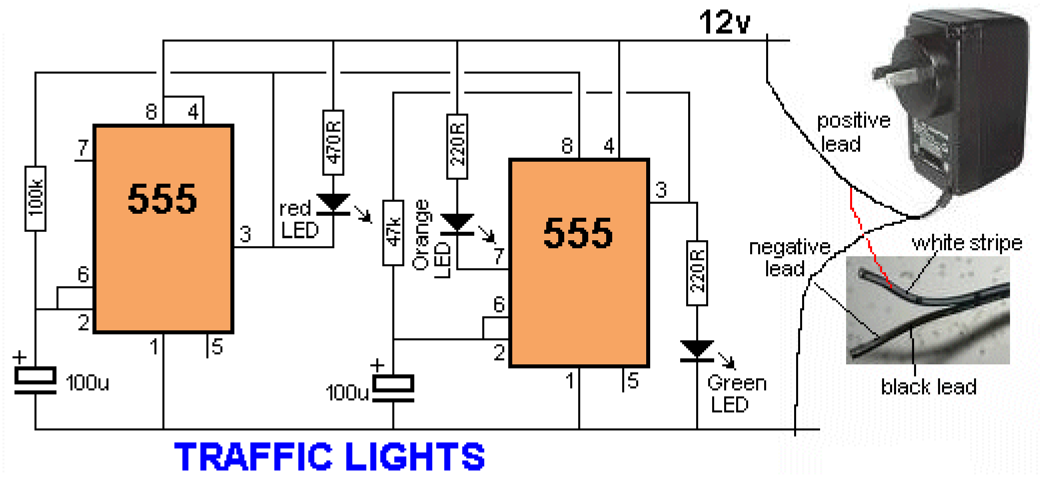


Neatness is not important. The important thing is to build as many circuits as possible as each one will help you understand how the 555 works and how the external circuitry modifies the signal to produce the resulting effect. There is a point-to-learn in every circuit.

POWERING A PROJECT

The safest way to power a project is with a battery. Use 4 x AA cells in a holder or a 9v battery if you only want to use the project for a short period of time.
If you want to use a 555 project for a long period of time you will need a "power supply."
The safest power supply is a Plug Pack (wall-wort, wall wart, wall cube, power brick, plug-in adapter, adapter block, domestic mains adapter, power adapter, or AC adapter). The adapter shown in the diagram has a switchable output voltage: 3v, 6v, 7.5v, 9v, 12v) DC and is rated at 500mA. The black lead is negative and the other lead with a white stripe (or a grey lead with a black stripe) is the positive lead.
This is the safest way to power a project as the insulation (isolation) from the mains is provided inside the adapter and there is no possibility of getting a shock.
The rating "500mA" is the maximum the Plug Pack will deliver and if your circuit takes just 50mA, this is the current that will be supplied. Some pluck packs are rated at 300mA

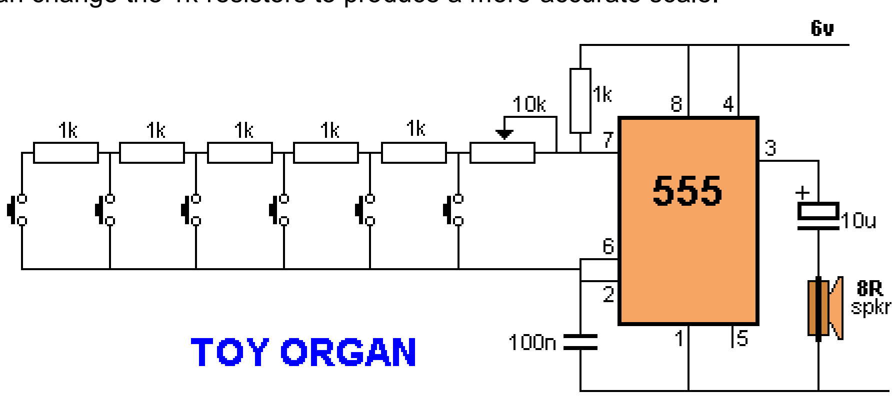
or 1A and some have a fixed output voltage. All these plug packs will be suitable. Some Plug Packs are marked "12vAC." This type of plug pack is not suitable for these circuits as it does not have a set of diodes and electrolytic to convert the AC to DC. All the circuits in this eBook require DC.



PROJECTS

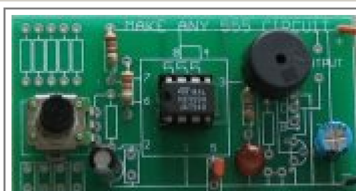
TOY ORGAN

This circuit produces a tone according to the button being pressed. Only 1 button can be pressed at a time, that's why it is called a monophonic organ. You can change the 1k resistors to produce a more-accurate scale.

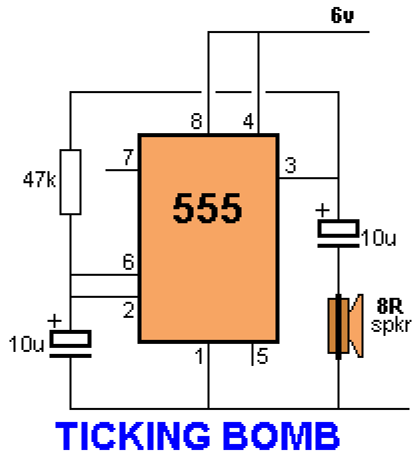


TICKING BOMB

This circuit sound just like a ticking bomb.

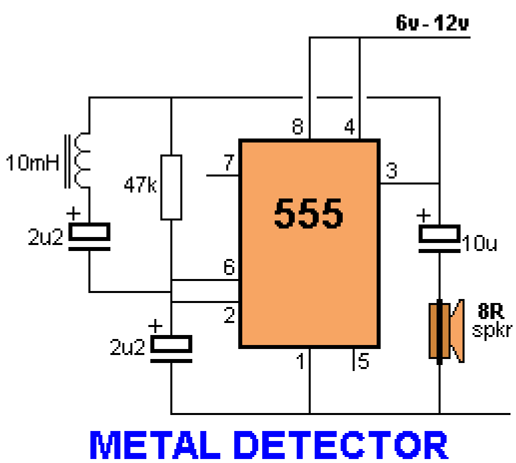


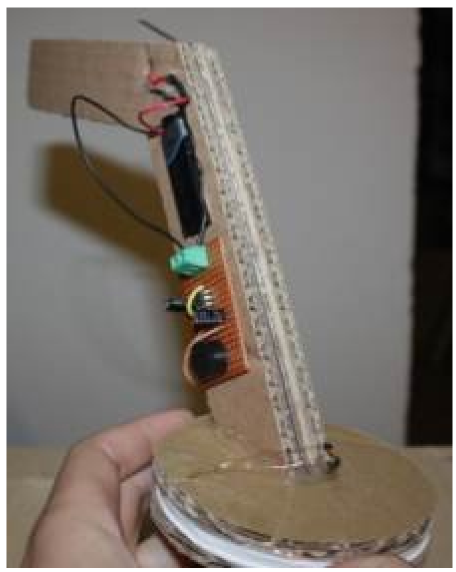
This project can be constructed on our [MAKE ANY 555 PROJECT] printed circuit board.



METAL DETECTOR

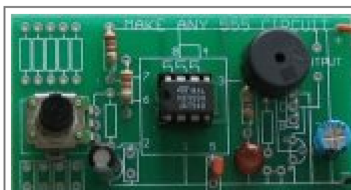
This circuit detects metal and also magnets. When a magnet is brought close to the 10mH choke, the output frequency changes. The photo shows the circuit made by a reader:



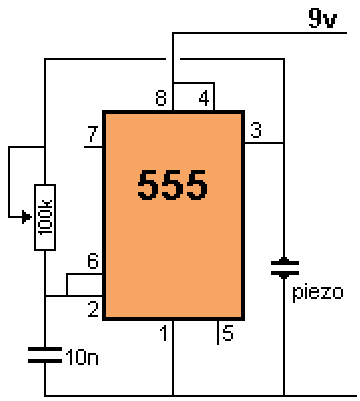


GUITAR TUNER

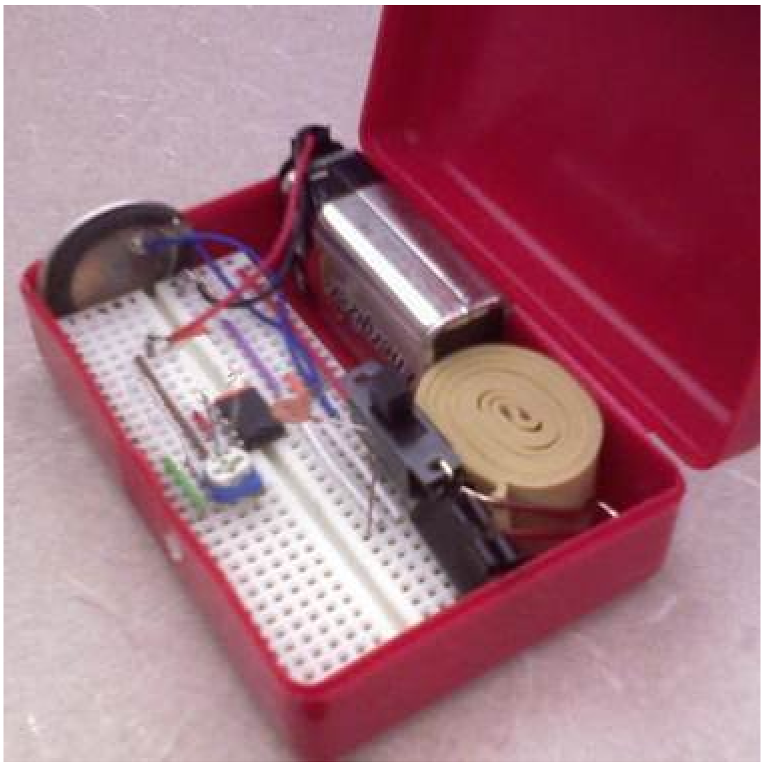
This circuit is designed to produce a tone of 440Hz.
To do this: Set the potentiometer to about half a turn with a small screw driver. Used an electronic keyboard and select the square wave tone, then turn on the Guitar Tuner circuit. Hold the A4 key down on the keyboard and use the screwdriver to turn the potentiometer until the frequencies match.



This project can be constructed on our MAKE ANY 555 PROJECT printed circuit board.

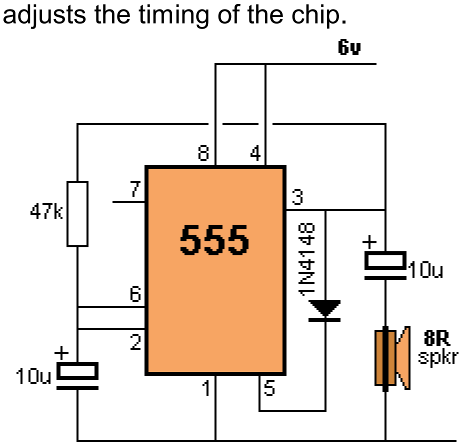


GUITAR TUNER



UNEVEN CLICKS

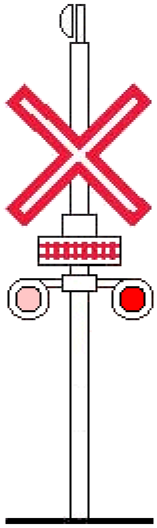
This circuit produces two clicks then a short space before two more clicks etc. Changing the voltage on pin, 5 via the diode, adjusts the timing of the chip.

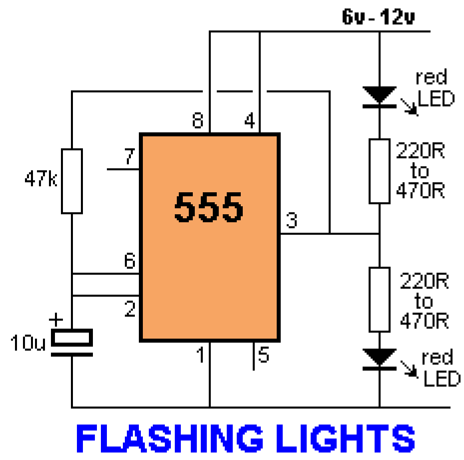


UNEVEN CLICKS

FLASHING RAILROAD LIGHTS

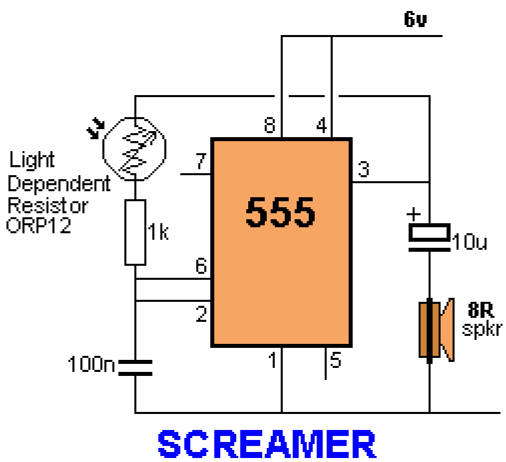
This circuit flashes two red LEDs for a model railway crossing.

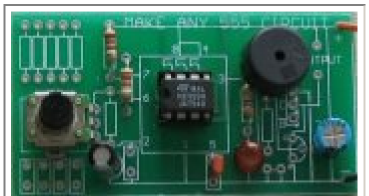




SCREAMER

This circuit will produce an ear-piercing scream, depending on the amount of light being detected by the Light Dependent Resistor.

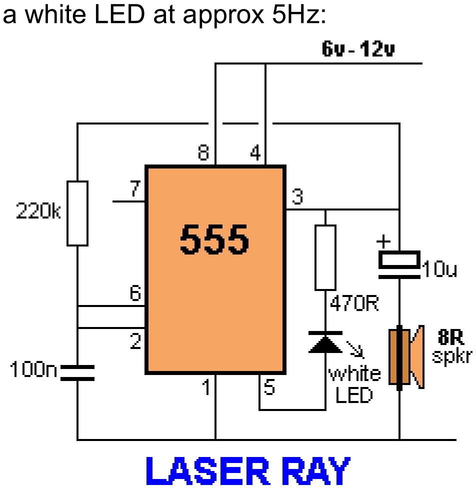




This project can be constructed on our **[MAKE ANY 555 PROJECT]** printed circuit board.

LASER RAY

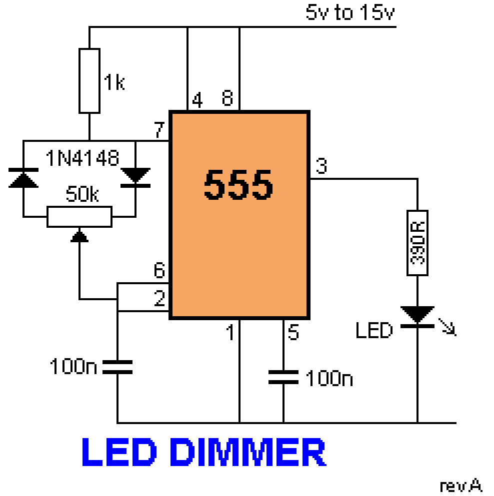
This circuit produces a weird "Laser Ray" sound and flashes a white LED at approx 5Hz:



Here is a video of the sound. It sounds much better with a large speaker.

LED DIMMER

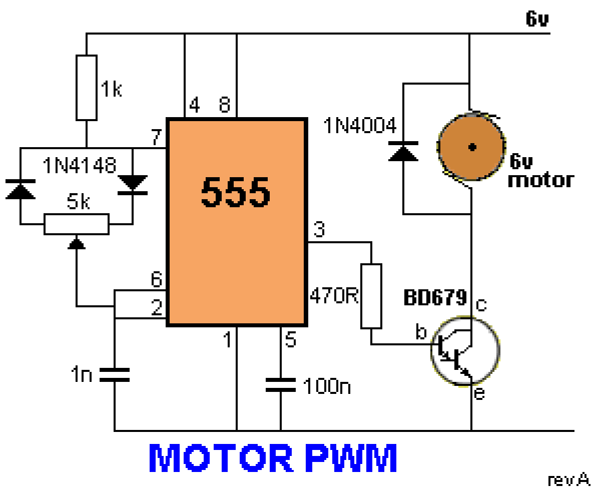
This circuit will adjust the brightness of one or more LEDs from 5% to 95%.



MOTOR PWM

See also: **PWM Controller**

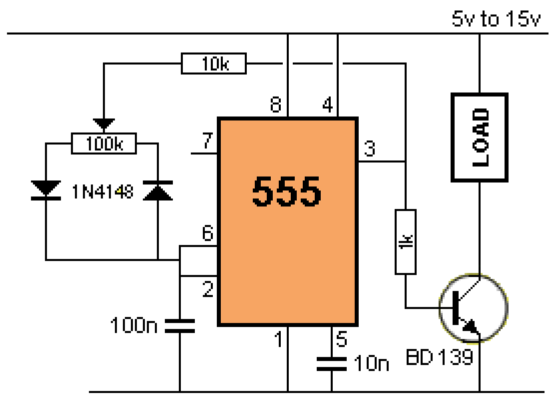
The speed of a motor can be adjusted by this circuit, from 5% to 95%.

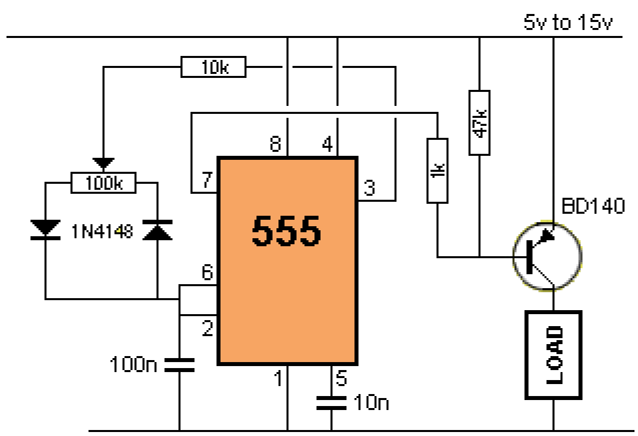


PWM

See also: **PWM Controller**

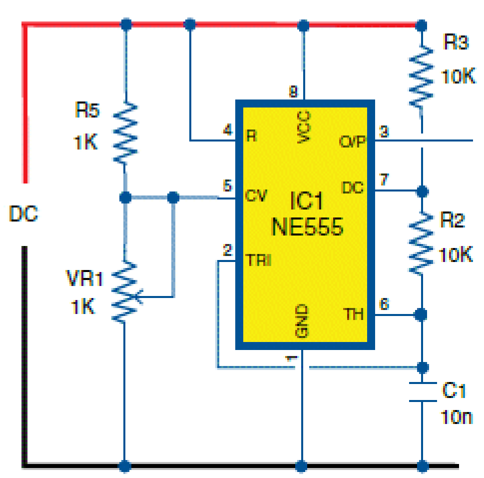
The output of these circuits can be adjusted from 5% to 95%.





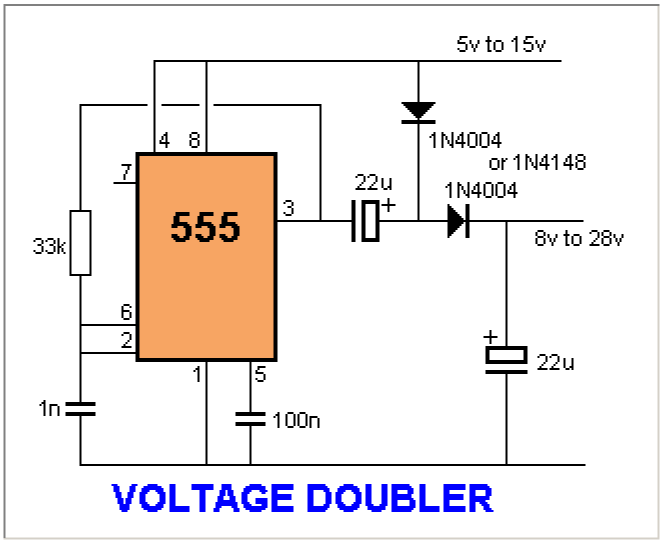
PWM via pin 5

The ratio of the HIGH time to the LOW time can be adjusted by changing the voltage on Pin 5. This is called PULSE-WIDTH adjustment or PULSE-WIDTH -MODULATION.
It does not give the wide range of the circuits above, but is handy for some applications.



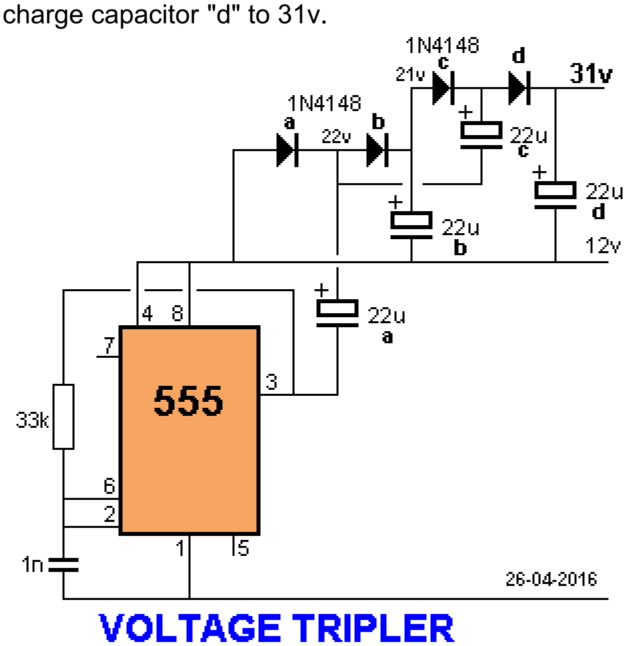
VOLTAGE DOUBLER

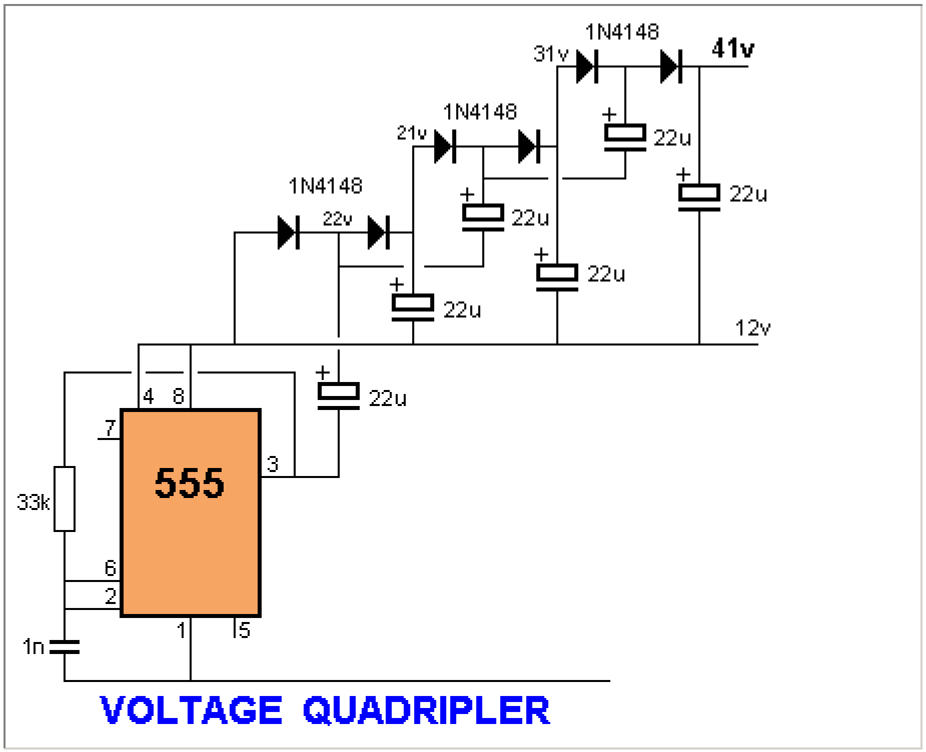
A voltage higher than the supply can be created by a "Charge-Pump" circuit created with a 555, diodes and capacitors as shown in the following circuit. The output will deliver about 50mA



VOLTAGE TRIPLER and QUADRIPLER!

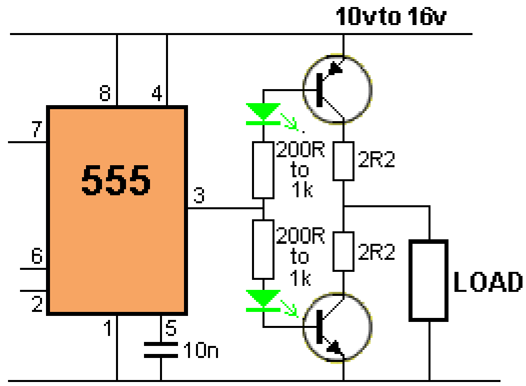
A voltage of about 3 times the supply (minus about 5v) can be created by the following circuit. The output will deliver about 50mA. Pin 3 goes LOW to about 0.5v and HIGH to about 11v.
When pin 3 goes LOW, capacitor "a" charges via diode "a" to about 11v. When pin 3 goes HIGH, capacitor "a" has about 11v across it, plus the voltage on pin 3. The 22v on the positive lead of capacitor "a" passes through diode "b" to charge capacitor "b" with 21v - 12v = 9v. This produces a voltage of 21v on the anode of diode "c." When pin 3 goes LOW, both capacitors "a" and "c" will charge via diodes "a" and "c" with capacitor "a" being charged via diode "a" and capacitor "c" charged via diode "c." When pin 3 goes HIGH, the 9v across capacitor "c" will be added to the 22v to charge capacitor "d" to 31v.



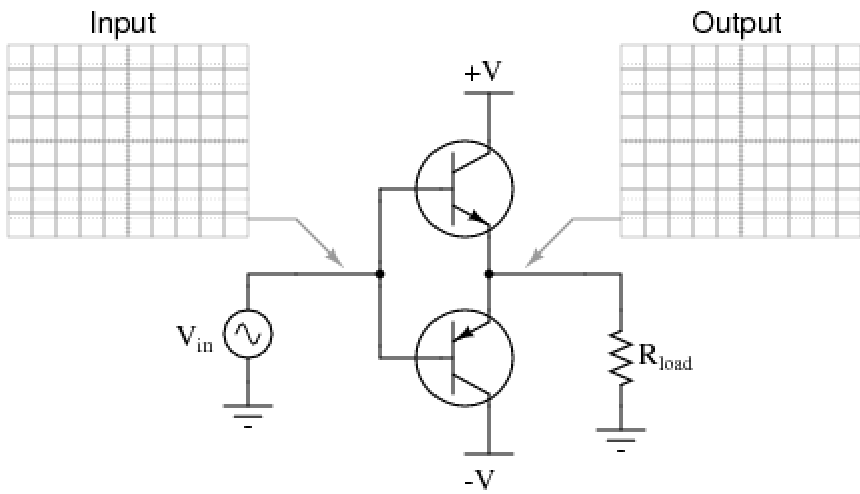


INCREASING OUTPUT PUSH-PULL CURRENT

Some 555's do not swing rail-to-rail when 200mA is being delivered and the chip gets very hot when trying to deliver 200mA.
The solution is to add a push-pull output. The following arrangement has been chosen as it swings almost rail-to-rail but two faults need to be addressed.
Both transistors turn on during the brief interval when pin 3 is travelling from high to low or low to high.
This means the two transistors will put a "short" across the power rail.
The addition of the 4R4 will allow a high current to flow but the transistors will not be damaged. In addition, green LEDs on the base of each transistor reduces the time when both transistors are ON.
The animation shows how the transistors are turned on and off and deliver a high current to the load. The animation shows how NPN and PNP transistors follow an input signal in a push -pull arrangement using positive and negative supply rails. This is not the same as our circuit however the basic effect applies. The output is inverse of pin3 but pin3 only needs to deliver 10-50 milliamp and the transistors can deliver 1 amp or more to the load. This allows the 555 to be kept cool.

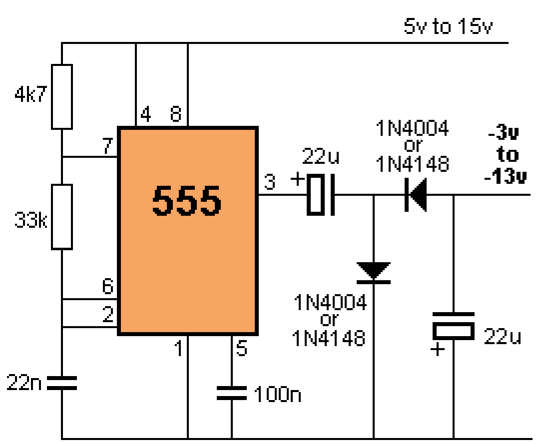


INCREASING PUSH-PULL OUTPUT CURRENT



NEGATIVE VOLTAGE

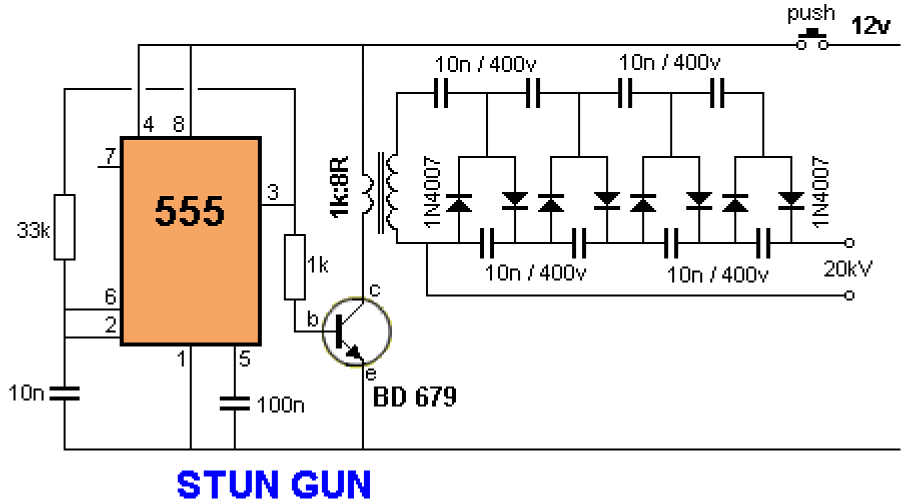
A negative supply can be produced by a "Charge-Pump" circuit created with a 555, diodes and capacitors as shown in the following circuit. The output will deliver about 50mA.



NEGATIVE VOLTAGE

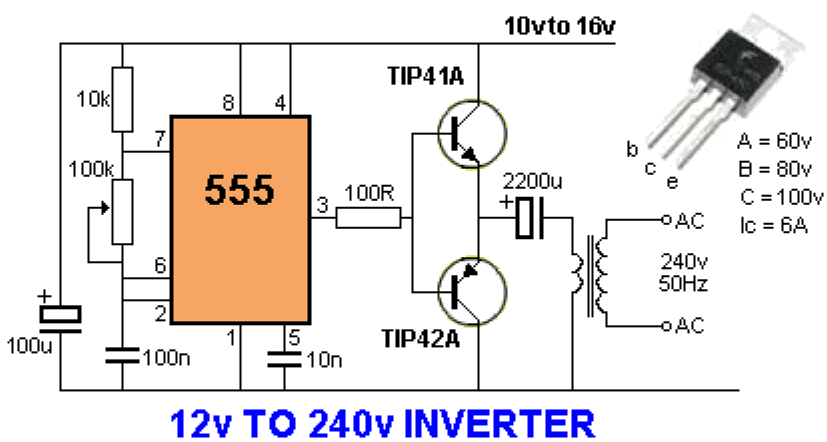
STUN GUN - Voltage Multiplier

This circuit produces a very high voltage and care must be used to prevent getting a nasty shock. The transformer can produce over 1,000v and the 8-stage multiplier can produce up to 20,000v



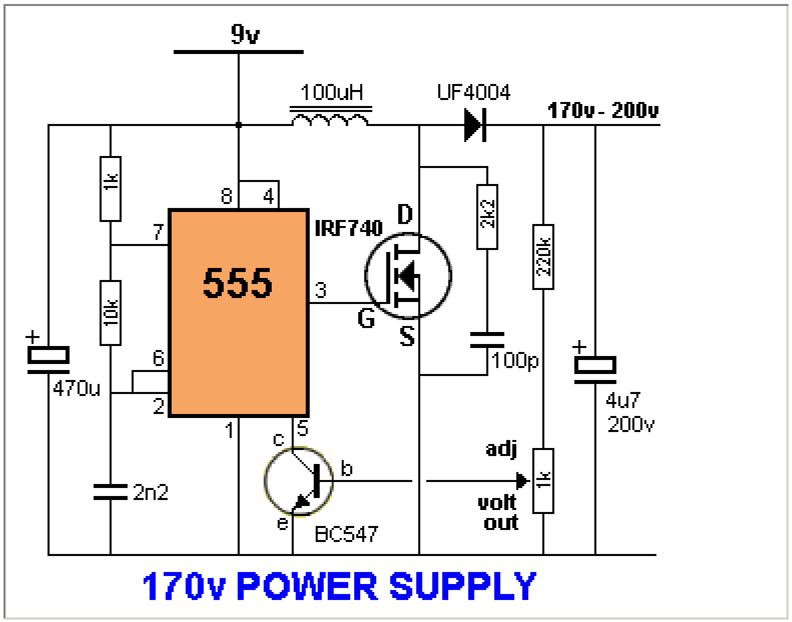
12v to 240v INVERTER

This circuit will produce 240v at 50Hz. The wattage will depend on the driver transistors and transformer.



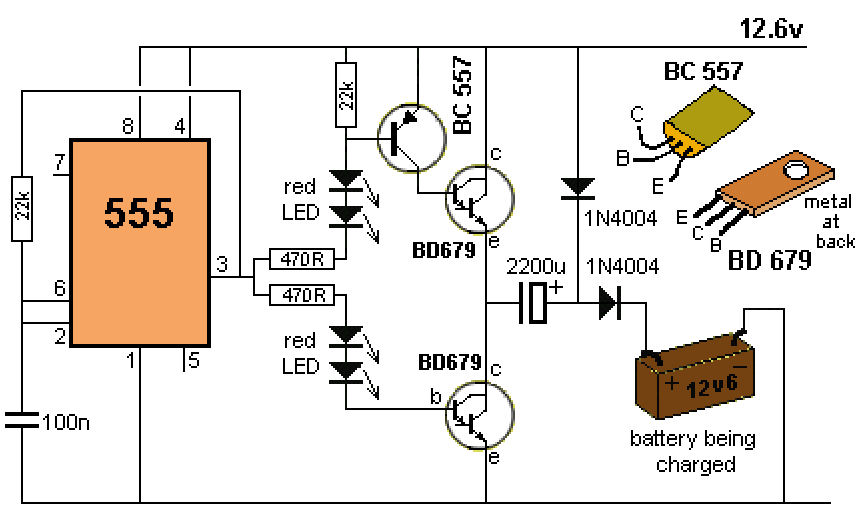
170v SUPPLY FOR NIXIE TUBES

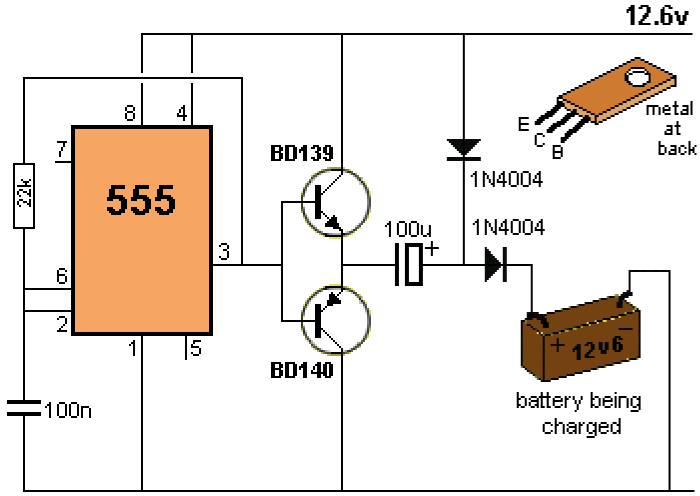
This circuit produces approx 170v for Nixie tubes and other neon tubes. It is a switch-mode boost circuit.



12v DC to 12v DC BATTERY CHARGER (and 19v see below)

You cannot charge a 12v battery from a 12v battery. The battery being charged creates a "floating charge" or "floating voltage" that is higher than the charging voltage and the charging stops.
The following circuit produces a voltage higher than 12v via a CHARGE PUMP arrangement in which the energy in an electrolytic is fed to a battery to charge it.
The circuit produces about 900mA "charge current" and the diodes and transistors must be fitted with heat sinks. The LEDs are designed to prevent the two output transistors turning ON at the same time. The lower output transistor does not start to turn on until the voltage is above 5v and the top transistor does not turn on until the voltage drops 4v from the positive rail. This means both transistors will be turned on ONLY when the voltage passes a mid-point-gap of 4v. In our circuit, this time is very short and and the transition is so fast that no current (short-circuit current) flows via the two output transistors (as per our test).
The electrolytic charges to about 10v via the lower transistor and top diode. The top BD679 then pulls the negative of the 2200u electrolytic towards the 12v6 rail and the positive is higher than 12v6 by a theoretical 10v, (about 9v in our case) however we need the ENERGY IN THE ELECTROLYTIC and in our circuit it is capable of delivering a current of about 900mA. This energy is passed to the battery via the lower diode. Most batteries should not be charged faster than the "14-hour-rate." This basically means a flat battery will be charged in 14 hours. To do this, divide the AHr capacity by 14 to get the charge-rate. For example, a 17AHr battery should be charged at 1.2A or less. For lower-capacity batteries, the 2200u can be reduced to 1,000u. Charging is about 80% efficient. In other words, delivering 120% of the AHr capacity of a battery is needed to fully charge it.





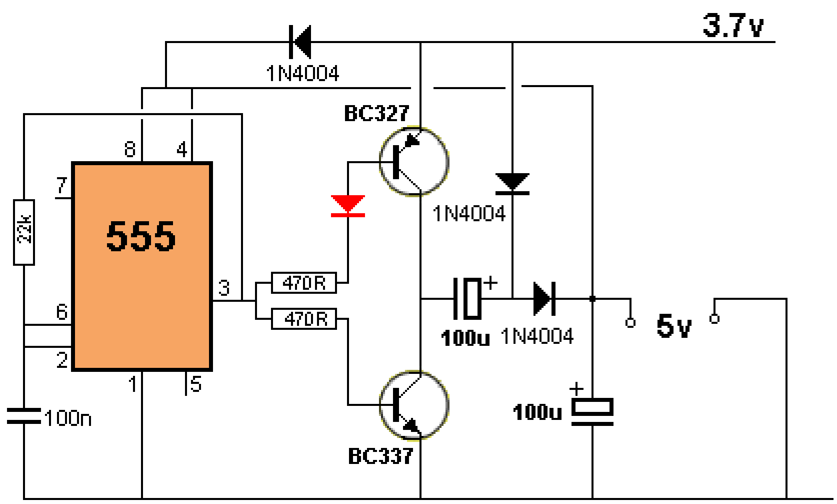
This circuit will deliver about 150mA

12v DC to 19v DC

This circuit can also be used to charge some of the older-style laptops that need a 19v supply. Remove the 12v battery from the circuit above and connect the cathode of the lower 1N4004 to the input of the laptop.

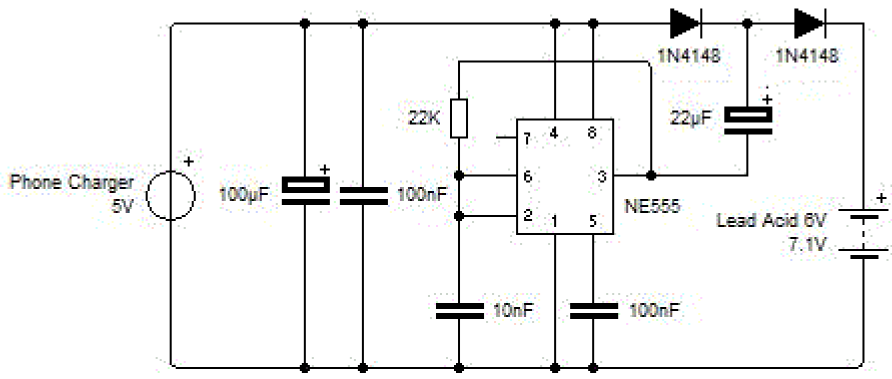
3.7v DC to 5v DC

This circuit will produce about 5v from a 3.7v Li-Ion cell:



5v DC to 7v DC

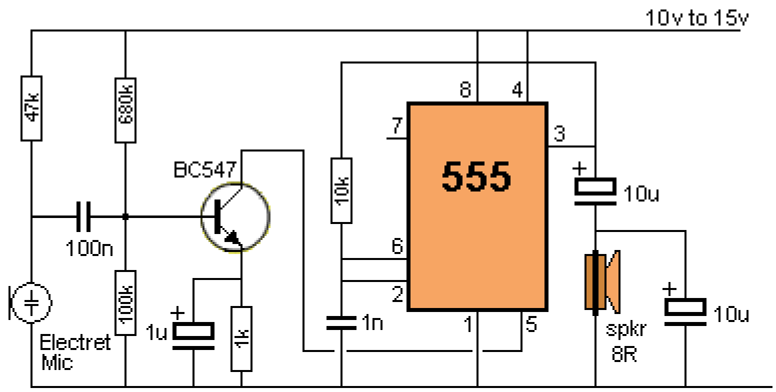
This circuit will produce about 7v from a 5v USB port or 5v cell-phone charger to trickle charge a 6v battery.
The voltage of the battery will rise to about 7v when charging (called the "floating charge") and that's why you need to "jack-up" the voltage from the USB port to charge the battery. The circuit is limited to about 45mA with a 22u electrolytic and a battery can take up to a week to charge.
Circuit design by: budiyantosamuel90@gmail.com



This circuit will deliver about 45mA

555 AMPLIFIER

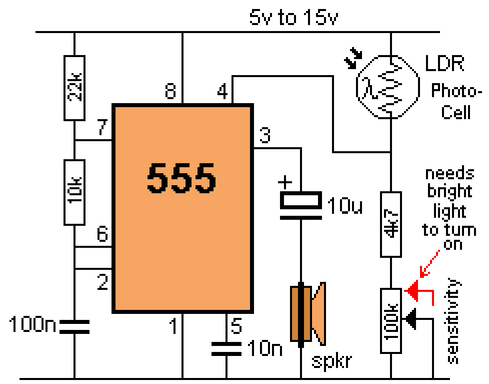
The 555 can be used as an amplifier. It operates very similar to pulse-width modulation. The component values cause the 555 to oscillate at approx 66kHz and the speaker does not respond to this high frequency. Instead it responds to the average CD value of the modulated output and demonstrates the concept of pulse-width modulation. The chip gets very hot and is only for brief demonstrations.



555 AMPLIFIER

LIGHT DETECTOR

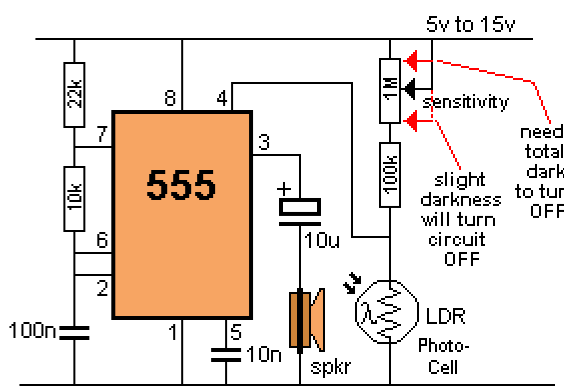
This circuit detects light falling on the Photo-cell (Light Dependent Resistor) to turn on the 555 and create a tone that is delivered to the speaker. Pin 4 must be held below 0.7v to turn the 555 off. Any voltage above 0.7v will activate the circuit. The adjustable sensitivity control is needed to set the level at which the circuit is activated.
When the sensitivity pot is turned so that it has the lowest resistance (as shown in red), a large amount of light must be detected by the LDR for its resistance to be low. This produces a voltage-divider made up of the LDR and 4k7 resistor. As the resistance of the LDR decreases, the voltage across the 4k7 increases and the circuit is activated.
When the sensitivity control is taken to the 0v rail, its resistance increases and this effectively adds resistance to the 4k7. The lower-part of the voltage-divider now has a larger resistance and this is in series with the LDR. Less light is needed on the LDR for it to raise the voltage on pin 4 to turn the 555 on.



LIGHT DETECTOR

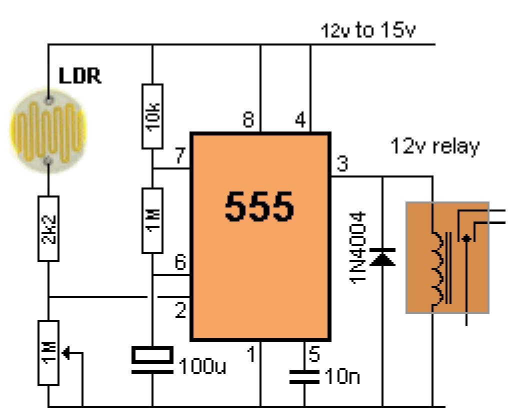
DARK DETECTOR

When the level of light on the photo-cell decreases, the 555 is activated. Photo-cells (Photo-resistors) have a wide range of specifications. Some cells go down to 100R in full sunlight while others only go down to 1k. Some have a HIGH resistance of between 1M and others are 10M in total darkness. For this circuit, the LOW resistance (the resistance in sunlight) is the critical value. More accurately, the value for a particular level of illumination, is the critical factor. The sensitivity pot adjusts the level at which the circuit turns on and allows almost any type of photo-cell to be used.



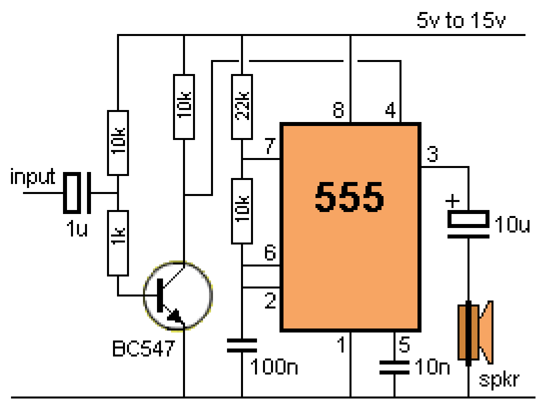
DARK DETECTOR

The next circuit turns on a relay for a short period of time when the LDR does not detect sufficient light:



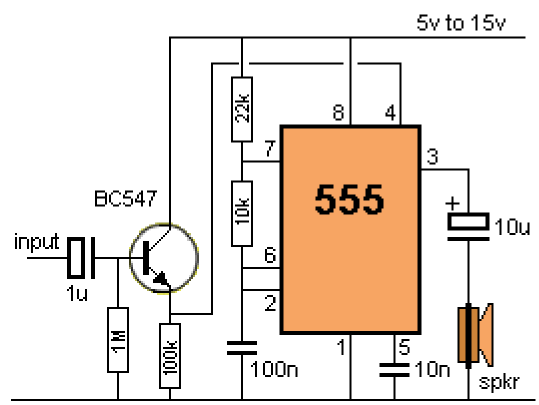
SHORT BEEP

This circuit produces a short beep when the input goes from HIGH to LOW. The input can stay LOW for any length of time but the output will always be a short beep.

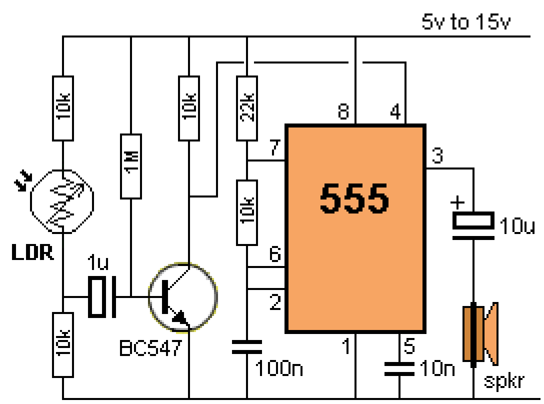


SHORT BEEP

This circuit produces a short beep when the input goes from LOW to HIGH. The length of the beep-tone depends on the value of the 1u electrolytic.



SHORT BEEP - a



SHORT BEEP with LDR

This circuit produces a short beep when the LDR does not receive any illumination.
The length of the beep-tone depends on the value of the 1u and the 10k connected to it.

Don't forget:

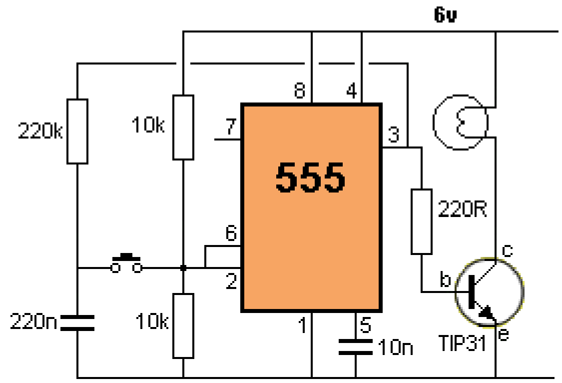
The 555 still takes 10mA when it is "turned off" via pin 4.
Pin 4 merely stops the output changing state.

FLIP FLOP and MEMORY CELL

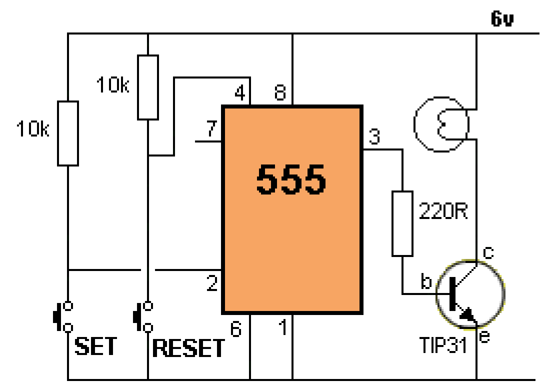
When output pin 3 is HIGH, the 220n charges through the 220k to 6v. When pin 3 is LOW, the 220n discharges through the 220k to 0v. Pressing the switch upsets the 3v created by the two 10k voltage dividers, triggering the flip flop inside the 555 and changing the state of the output from HIGH to LOW or *vice-versa.* The output of the 555 drives a transistor to turn a globe on and off.

The second circuit is a Memory cell and is the basis of the memory in a computer. The SET button turns on the globe and the RESET button turns the globe off.

It works like this: When the circuit is turned on, pin 6 does not see a high and pin 2 does not see a low, so the 555 starts in reset mode.



FLIP FLOP

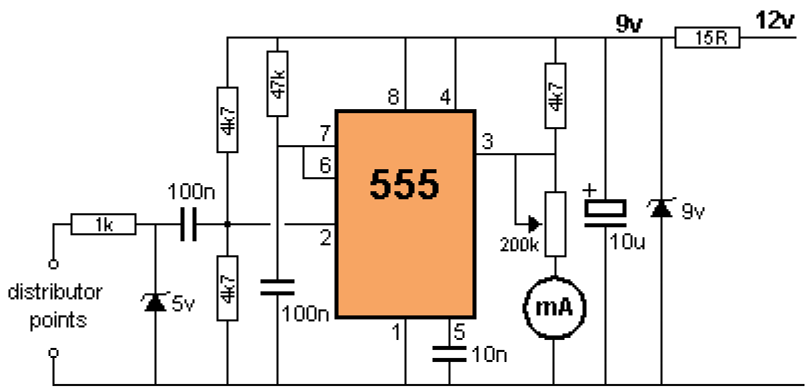


MEMORY CELL

CAR TACHOMETER

A 555 is configured as a monostable or one shot in this project. The period of the 555 is determined by the 47k and the capacitor from pin 6 to ground (100n). Time "T" = 1.1 RC or 1.1 X 50,000 X 0.1 $^{X10^{-6}}$ = 0.0055 or 5.5 mS (milli-seconds).

The 555 receives trigger pulses from the distributor points. These are limited by the 1k and 5v zener diode. These are AC coupled to the trigger input through the 100n coupling capacitor. The 50mA meter receives pulses of current through the 200k pot to show a reading.



CAR TACHOMETER

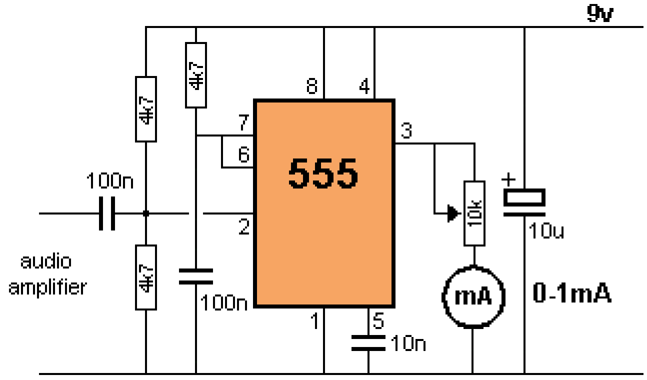
Integration of the current pulses produces a visible indication of the cars engine speed on the 0-1mA meter.

Supply is taken from the cars 12v system and for the 555 it is reduced to a regulated 9v by the 15 ohm resistor in conjunction with the 9v zener diode. Note: the 10u electrolytic must be placed physically as close as possible to supply pin 8.

FREQUENCY METER

This circuit will detect audio frequencies and display them on a meter (actually called a "movement"). Connect the circuit to the output of an amplifier. It is best to detect one frequency at

a time.



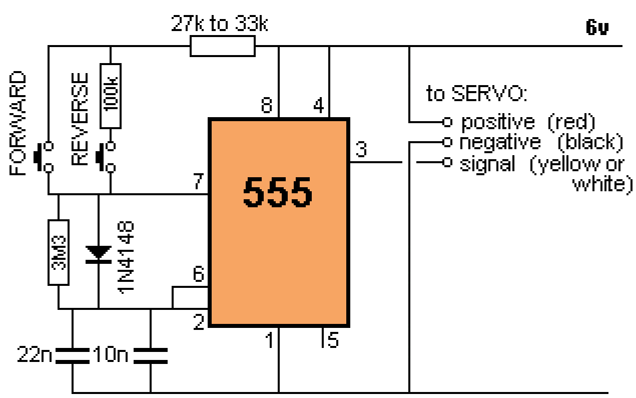
FREQUENCY METER

Integration of the audio frequency produces a visible indication on the 0-1mA meter.

SERVO TESTER

This circuit can be used to manually turn a servo clockwise and anti-clockwise. By pushing the forward or reverse button for a short period of time you can control the rotation of the servo. It will also test a servo.

Here is a photo of a kit from **Cana Kit** for $10.00 plus postage (it is a slightly different circuit) and a motor and gearbox, commonly called a "servo." The output shaft has a disk or wheel containing holes. A linkage or push-rod is fitted to a hole and when the disk rotates, the shaft is pushed and pulled. The shaft only rotates about 180° to actuate flaps or ailerons etc.



SERVO TESTER

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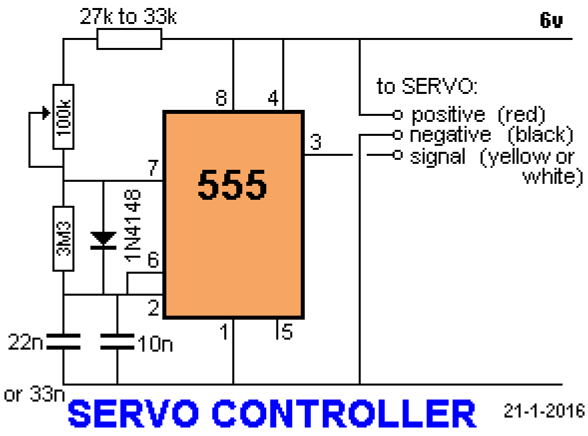
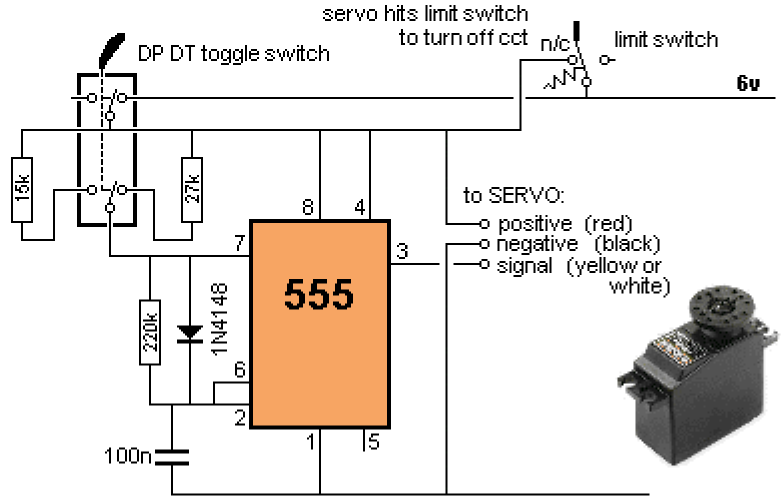


A pot can be used to control the position of the servo by using the following circuit. It produces a positive pulse between about 0.9 milliseconds and 2.1 milliseconds. The off period between pulses is about 40 milliseconds. This can be shortened by reducing the value of the 3M3 resistor.

USELESS MACHINE

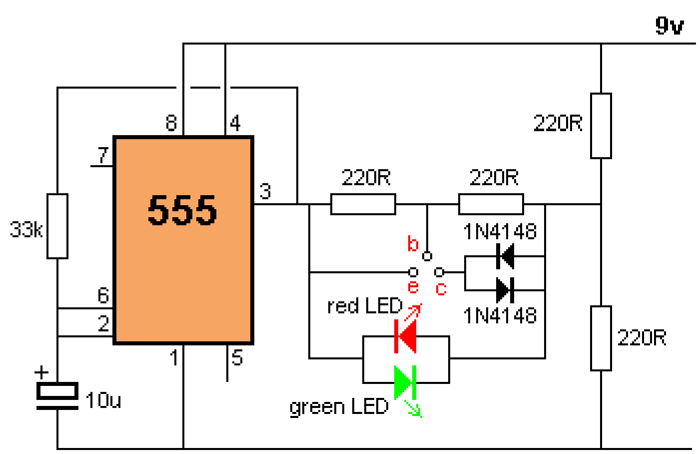
Here is a fun project using a servo motor and a circuit similar to the SERVO TESTER project above. It is available on the INSTRUCTABLES website. Before you do anything, watch the video:
http://www.instructables.com/id/The-Most-Useless-Machine



USELESS MACHINE

The Instructables website contains all the construction details. The circuit diagram shows the toggle switch is clicked towards the lid of the box and this starts the servo motor. The servo has an arm that comes out of the box and clicks the switch to the opposite position. This reverses the servo and the arm retreats into the box and hits the limit switch that turns the circuit off.
You may have to adjust the value of the 15k and 27k resistors and you will also see other videos on the Instructables website to help you with construction.
As the website says: "It's the most useless invention, but everyone wants one."

TRANSISTOR TESTER

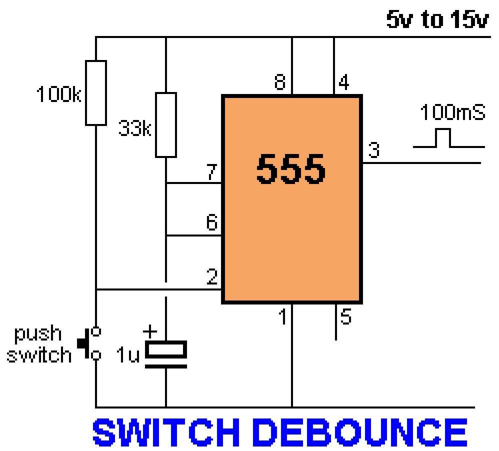


TRANSISTOR TESTER

The 555 operates at 2Hz. Output pin 3 drives the circuit with a positive then zero voltage. The other end of the circuit is connected to a voltage divider with the mid-point at approx 4.5v. This allows the red and green LEDs to alternately flash when no transistor is connected to the tester.
If a good transistor is connected, it will produce a short across the LED pair when the voltage is in one direction and only one LED will flash. If the transistor is open, both LED's will flash and if the transistor is shorted, neither LED will flash.

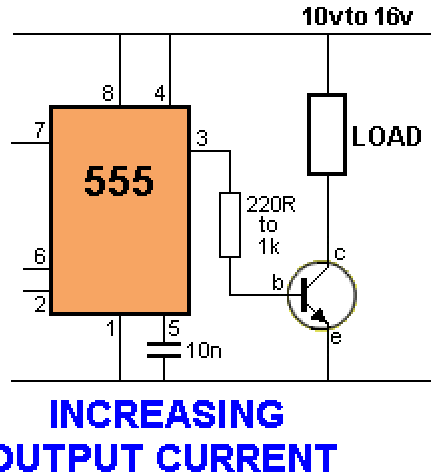
SWITCH DEBOUNCE

The output goes HIGH for 100mS when the switch is pressed.



INCREASING OUTPUT CURRENT

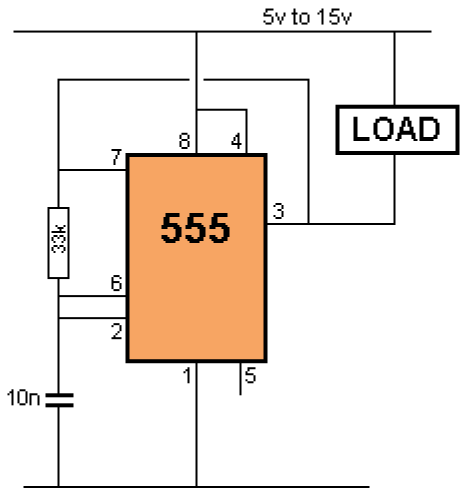
The 555 will deliver 200mA to a load but the chip gets extremely hot (12v supply). The answer is to use a buffer transistor.
For 200mA, use a BC547 or equivalent.
For 500mA use a BC337 or equivalent
For 1A, use a TIP31 or equivalent.
For 3A - 5A use a BD679 or equivalent with heatsink
For 5A to 10A use TIP3055 with heatsink



IMPROVING THE SINKING OF A 555

The output of a 555 goes low to deliver current to a load connected as shown in the circuit below. But when the chip is sinking 200mA, pin 3 has about 1.9v on it. This means the chip does not provide full rail voltage to the load.
This can be improved by connecting pin 7 to pin 3. Pin 7 has a transistor that connects it to 0v

rail at the same time when pin 3 is LOW. They can both be connected together to improve sinking capability. In this case the low will be 800mV for 200mA instead of 1900mV, an improvement of 1100mV. This will add 1v1 to the load and also make the chip run cooler.



IMPROVING THE OUTPUT

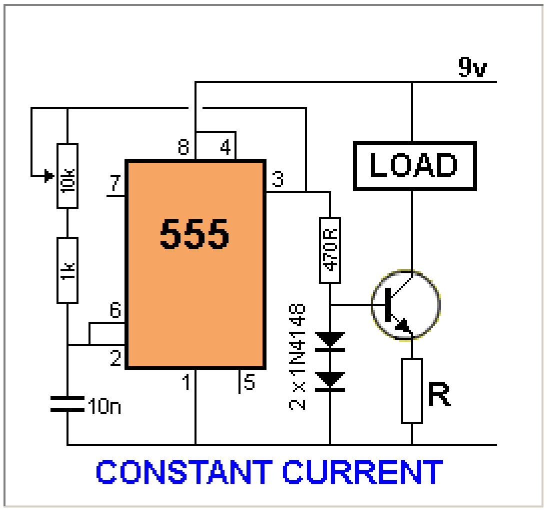
CONSTANT CURRENT

The 555 will deliver 200mA to a load but this might be too much. You can add a dropper resistor (current limiting resistor) but the current will reduce as the supply voltage drops.

To provide a constant output current to a device such as an IR LED, the following circuit can be used. The current will be constant for any supply voltage but the best range will be 7v to 12v.

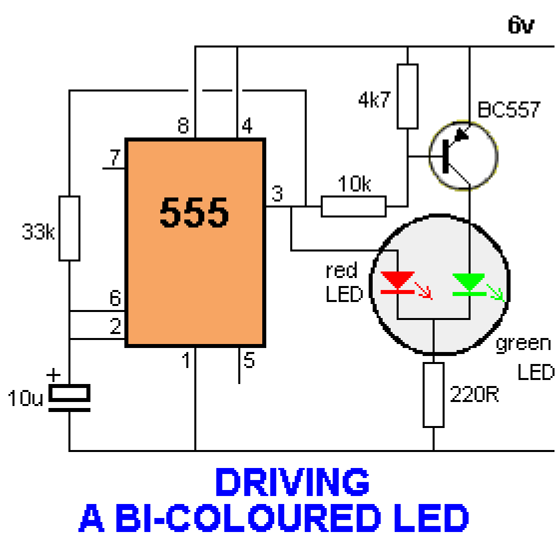
The current is determined according to the value of R. You can use this table:

R	Current
5R6	100mA
10R	60mA
22R	30mA
47R	15mA
100R	6mA



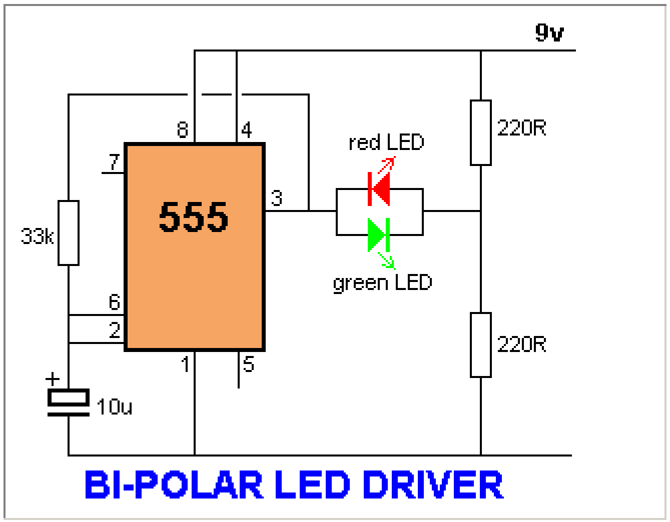
DRIVING A BI-COLOUR LED

Some 3-leaded LEDs produce red and green. This circuit alternately flashes a red/green bi-coloured LED:



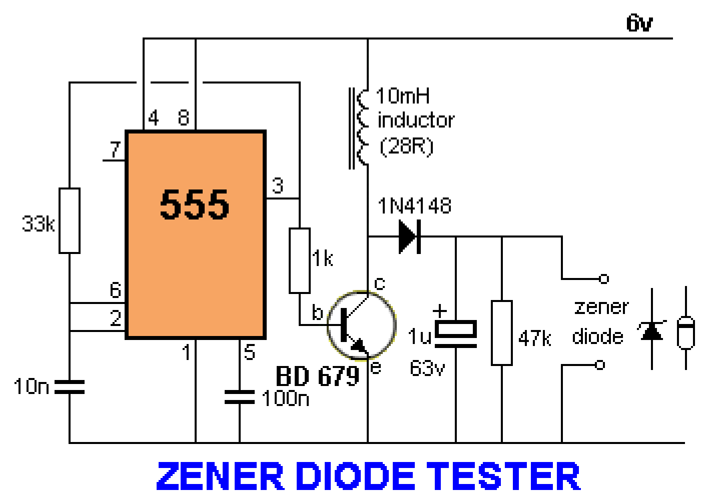
BI-POLAR LED DRIVER

Some 2-leaded LEDs produce red and green. These are called Bi-polar LEDs. This circuit alternately flashes a red/green bi-polar LED:



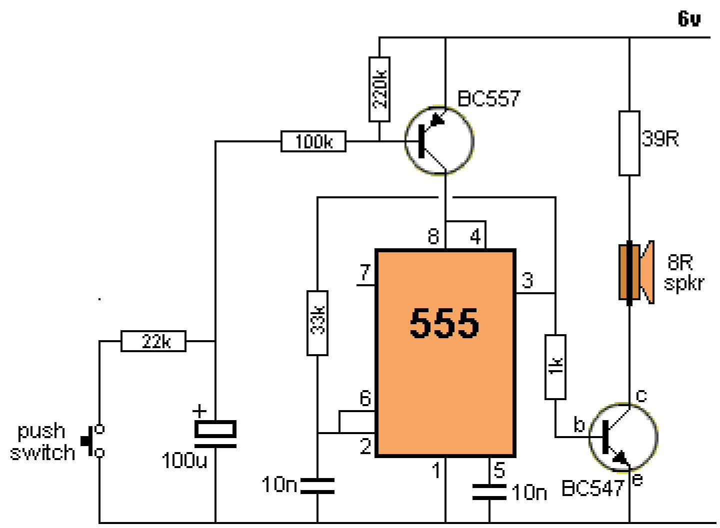
ZENER DIODE TESTER

This circuit will test zener diodes up to 56v. See Talking Electronics website, left index, 200 Transistor Circuits (circuits 1-100) and go to Zener Diode (making) to see how to make a zener diode and how to create a zener voltage from a combination of zeners.
Place the zener across the terminals in the circuit below and read the value across it with a multimeter set to 50v range.



WAILING SIREN

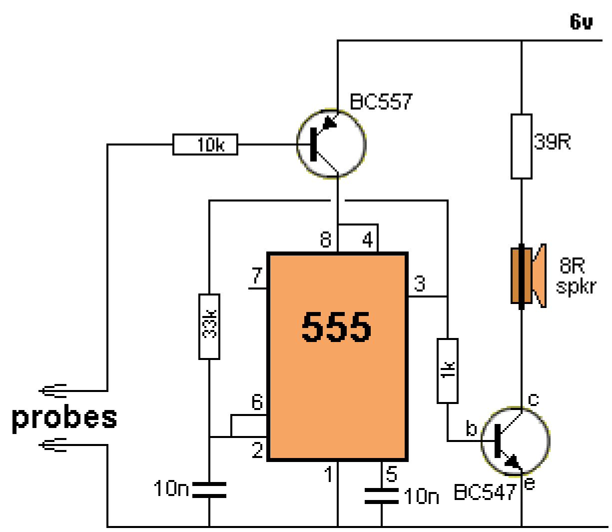
By pressing the button, the wailing sound increases.
Releasing the button decreases the wailing.
The circuit automatically turns off after about 30 seconds.



WAILING SIREN

CONTINUITY TESTER

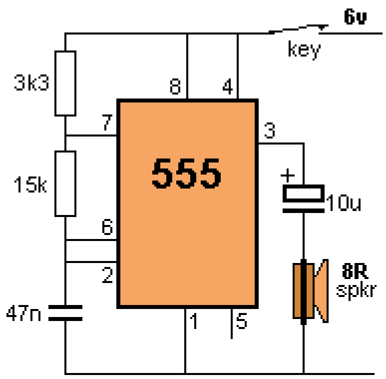
This circuit will detect low resistances and high resistances to produce a tone from the speaker.
It will detect up to 200k and the circuit automatically turns off when the probes are not used.

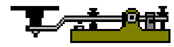


CONTINUITY TESTER

MORSE KEYER

This circuit will help you master the art of keying Morse Code:





MORSE KEYER

Morse Code:

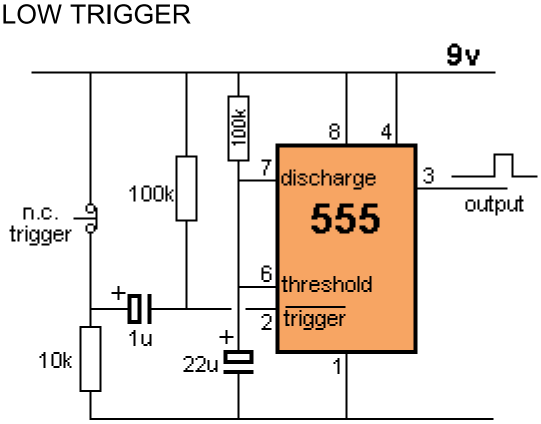
A .-	E .	I ..	M --	Q --.-	U ..-	Y -.--
B -...	F ..-.	J .---	N -.	R .-.	V ...-	Z --..
C -.-.	G --.	K -.-	O ---	S ...	W .--	
D -..	H	L .-..	P .--.	T -	X -..-	

International Phonetic Alphabet:

Alva	Echo	India	Mike	Quebec	Uniform	Yankee
Bravo	Foxtrot	Juliet	November	Romeo	Victor	Zulu
Charley	Golf	Kilo	Oscar	Sierra	Wiskey	
Delta	Hotel	Lima	Papa	Tango	X ray	

ACTIVE LOW TRIGGER

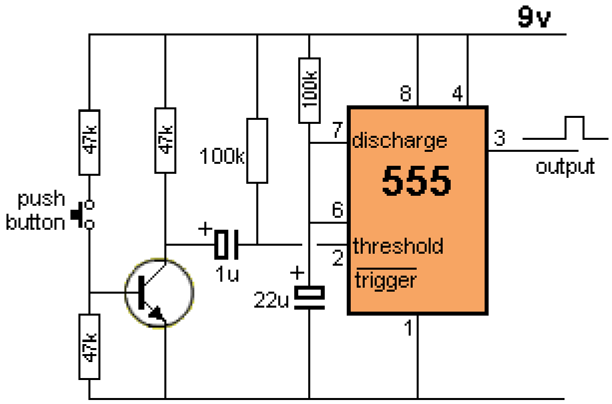
This circuit sits LOW and the output goes HIGH when the push-button is pressed. When the normally-closed push button is pressed, it opens and the uncharged 1u will be pulled to nearly 0v rail via the 10k and this will take pin 2 LOW to make output pin 3 HIGH for the duration determined by the 22u and 100k. If the push-switch stays open, the 1u will charge via the 100k and eventually the output of the 555 will go low.
But normally the switch must be pressed for a short period of time so that the timing components (100k and 22u) make the output go HIGH for a short period of time. This circuit is called an ACTIVE LOW TRIGGER



NORMALLY CLOSED TRIGGER
(also called ACTIVE LOW TRIGGER)

ACTIVE HIGH TRIGGER

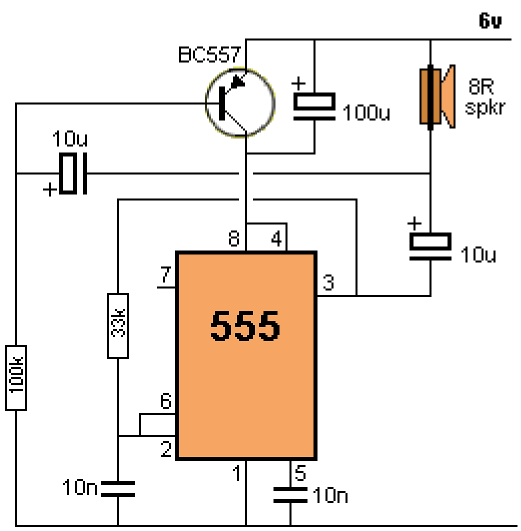
This circuit produces a HIGH output via a HIGH trigger:



ACTIVE HIGH TRIGGER

MACHINE GUN

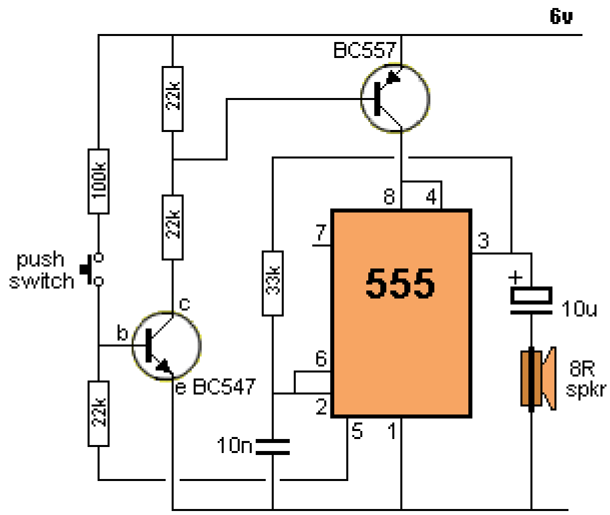
This circuit produces a sound very similar to a machine gun:



MACHINE GUN

LATCH

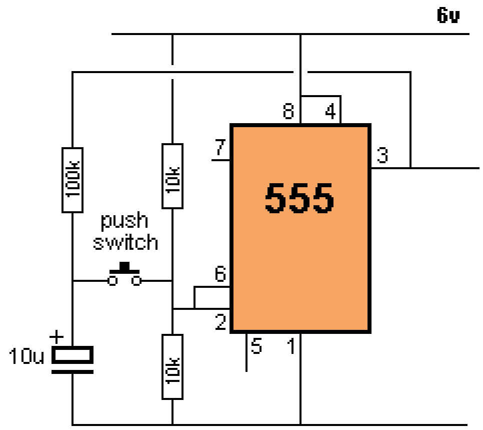
This circuit is a LATCH and remains ACTIVE when the push-button has been pressed for an INSTANT and released.



LATCH

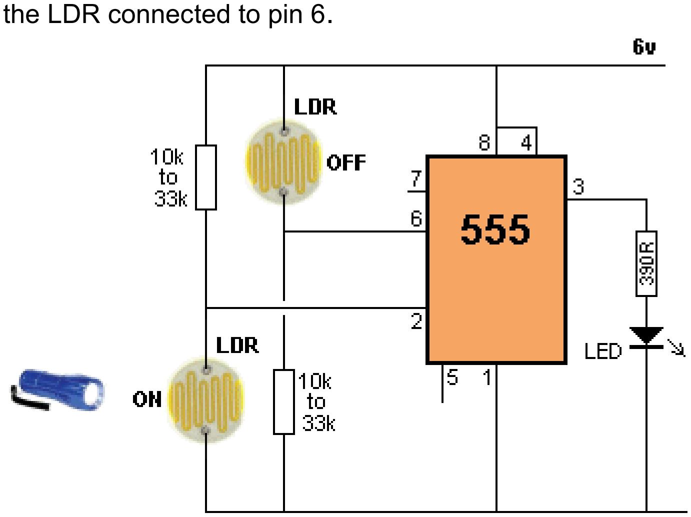
TOGGLE 555

This circuit will toggle the output each time the switch is pressed. The action cannot be repeated until the 10u charges or discharges via the 100k.



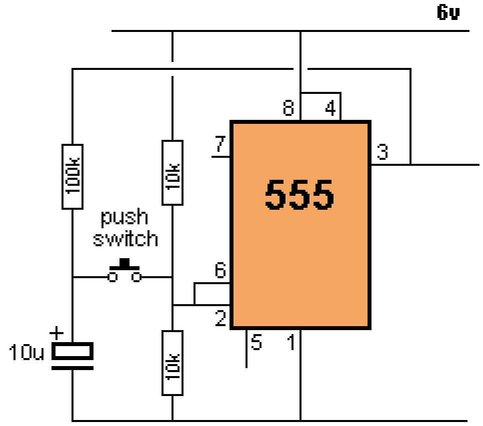
TOGGLE 555 - ON/OFF

This circuit will turn the output ON when a light shines on the LDR connected to pin 2 and OFF when a light shines on the LDR connected to pin 6.



TOGGLE A RELAY

This circuit will toggle a relay each time the switch is pressed. The action cannot be repeated until the 10u charges or discharges via the 100k.

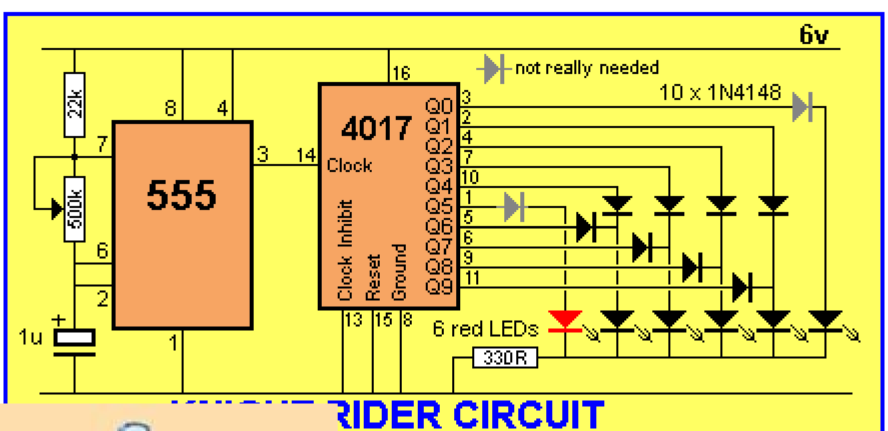


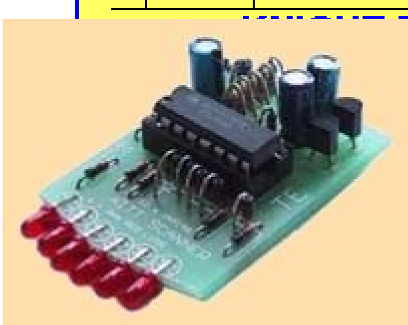
KNIGHT RIDER

In the **Knight Rider** circuit, the 555 is wired as an oscillator. It can be adjusted to give the desired speed for the display. The output of the 555 is directly connected to the input of a Johnson Counter (CD 4017). The input of the counter is called the CLOCK line.

The 10 outputs Q_0 to Q_9 become active, one at a time, on the rising edge of the waveform from the 555. Each output can deliver about 20mA but a LED should not be connected to the output without a current-limiting resistor (330R in the circuit above). The first 6 outputs of the chip are connected directly to the 6 LEDs and these "move" across the display. The next 4 outputs move the effect in the opposite direction and the cycle repeats. The animation above shows how the effect appears on the display.

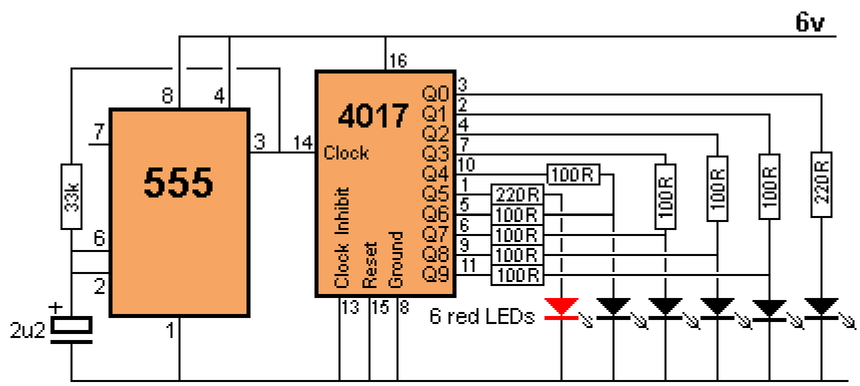
Using six 3mm LEDs, the display can be placed in the front of a model car to give a very realistic effect. The same outputs can be taken to driver transistors to produce a larger version of the display.





BUY NOW le as a kit for less than $15.00

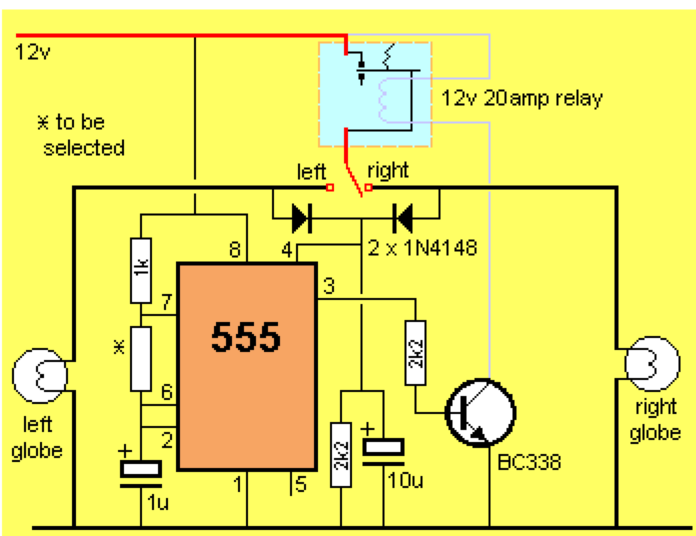
Here is a simple Knight Rider circuit using resistors to drive the LEDs. This circuit consumes 22mA while only delivering 7mA to each LED. The outputs are "fighting" each other via the 100R resistors (except outputs Q0 and Q5).



KNIGHT RIDER CIRCUIT-2

FLASHING INDICATORS

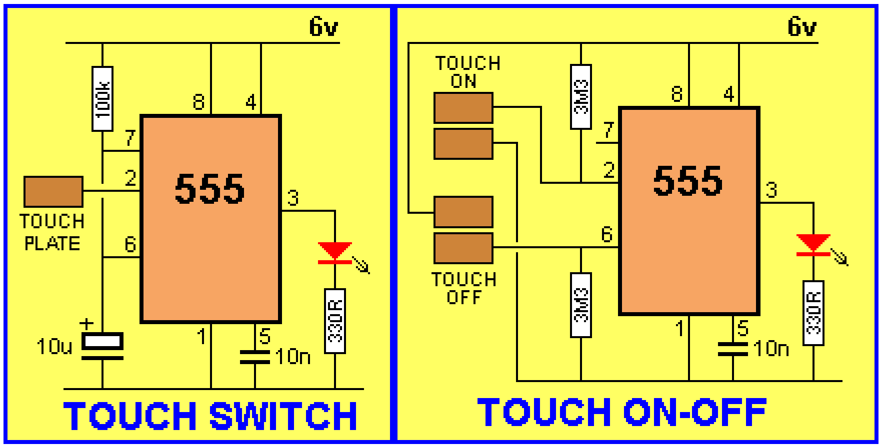
This is a request from Daniel, one of our subscribers.
He needed to flash "turn indicators" using a 555 and a single 20 amp relay. Here is our suggestion. The timing resistor needs to be selected for the appropriate flash-rate.



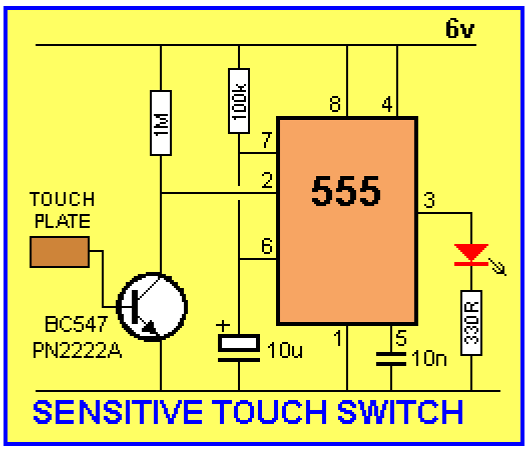
Flashing the "TURN INDICATORS"

TOUCH SWITCH and TOUCH ON-OFF

The **Touch Switch** circuit will detect stray voltages produced by mains voltages and electrostatic build-up in a room. In the first circuit, pin 2 must see a LOW for the circuit to activate. If sufficient static voltage is detected by the plate, the chip will change state. If not, you will need to touch the plate and the 0v rail. In the second circuit, two touch plates are provided and the resistance of your finger changes the voltage on pin 2 or 6 to toggle the 555.

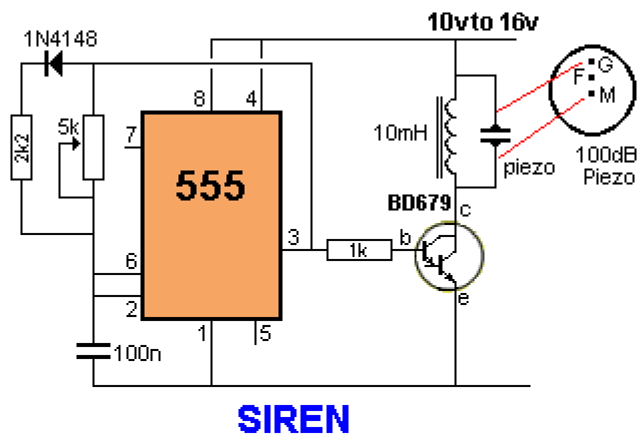


The circuit can be made 100 times more sensitive by adding a transistor to the front-end as shown in the diagram below:



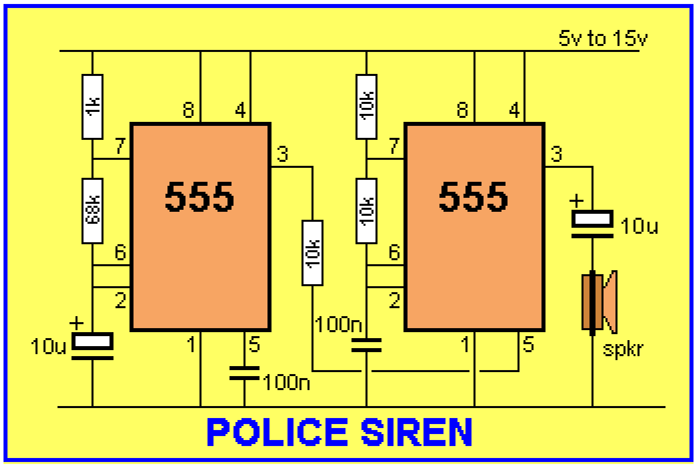
SIREN 100dB

This is a very loud siren and if two or more piezo's are located in a room, the burglar does not know where the sound is coming from.
A robber will not stay anywhere with an ear-piercing sound as he cannot hear if someone is approaching. It's the best deterrent you can get. The "F" contact on the piezo is "feedback" and is not needed in this circuit.



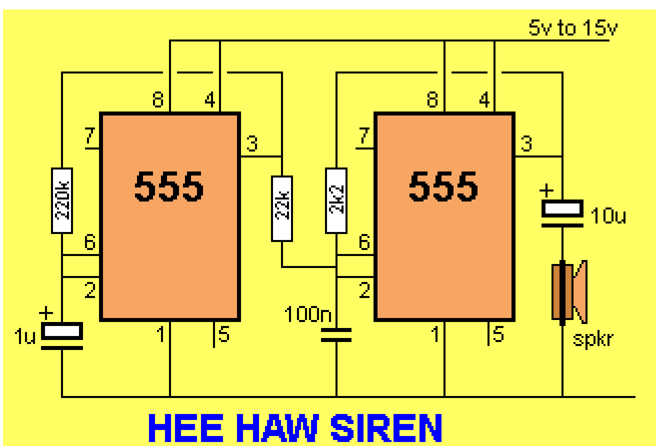
POLICE SIREN

The **Police Siren** circuit uses two 555's to produce an up-down wailing sound. The first 555 is wired as a low-frequency oscillator to control the **VOLTAGE CONTROL** pin 5 of the second 555. The voltage shift on pin 5 causes the frequency of the second oscillator to rise and fall.



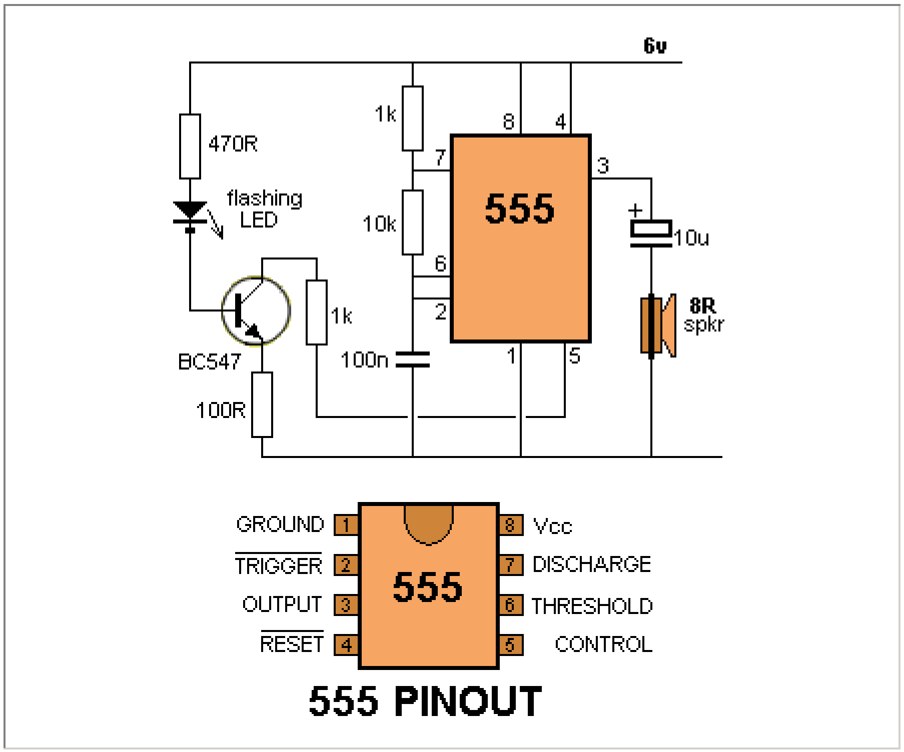
HEE HAW SIREN

Build the circuit and listen. Change the resistors and capacitors to get all sorts of different results.



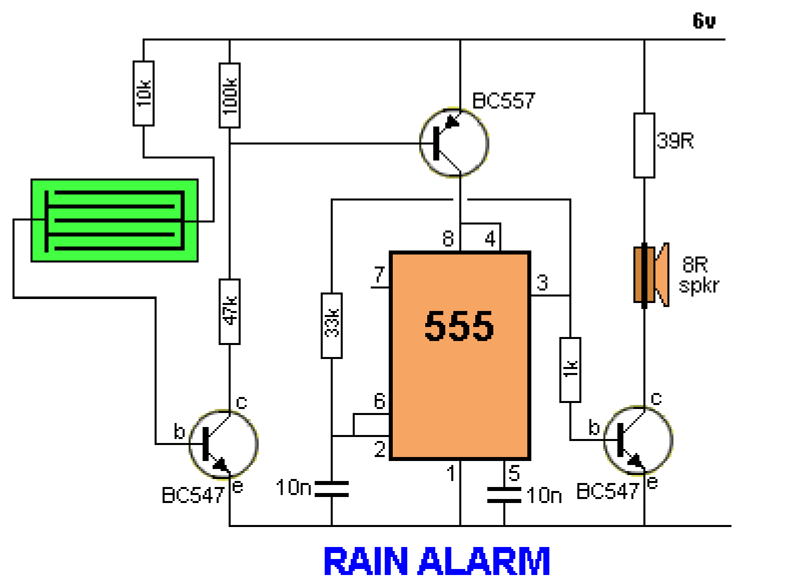
HEE HAW SIREN with one 555

The flashing LED is used to provide the timing and also to alter the 555 to produce two different tones.



RAIN ALARM

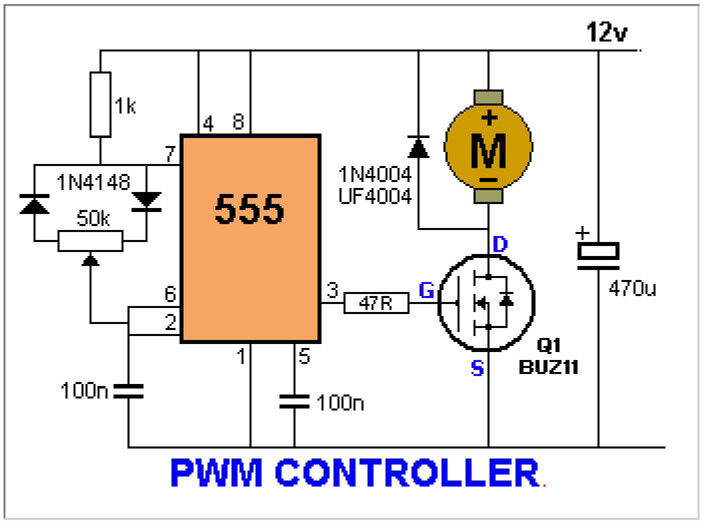
This circuit consumes no current until moisture is detected on the rain plate.



PWM CONTROLLER

See also: PWM

This controller will deliver up to 30 amps and control the motor from 5% to 95%.

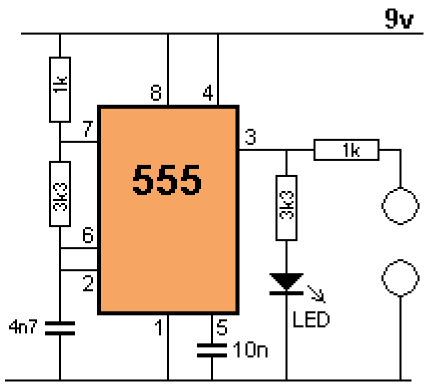


SOLAR TRACKER

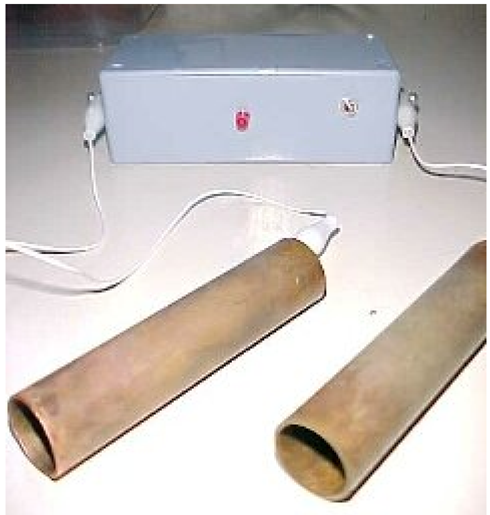
Some ideas are simply not suited for a 555. This is one. A solar tracker should consume little or no current when waiting for a the sun to change position. A 555 takes 10mA+ and suitable circuits using other chips will take less than 1mA. That's why we have not designed a 555 circuit.

HULDA CLARK ZAPPER

This is the circuit for Dr. Hulda Clark's Zapper, designed in 2003. The frequency is approximately 30kHz positive offset square wave. It has a red LED light that lights up when the unit is on. Perfect for regular zapping, extended zapping and other Hulda Clark related experiments.
This device is used to cure, treat and prevent any disease. It will cure anything. Simply hold the two probes (one in each hand) for 5-10 minutes then rest for 20 minutes, then repeat two more times. Do this each day and you will be cured. Here is the .pdf of her book: A Cure For All Diseases. Website: http://clarktestimonials.com/
Hundreds of people have been cured of everything from herpes to AIDS.
On the other side of the coin is the claim that Dr Hulda Clark is a complete quack. Here is a website called: Quackwatch. The second diagram shows the two copper tubes and the circuit in a plastic box. I am still at a loss to see how any energy can transfer from this quack machine, through the skin (50k skin resistance and 9v supply) and zap a bug in your intestine. It's a bit like saying I will kill all the mice in a haystack by stabbing the stack with a needle.

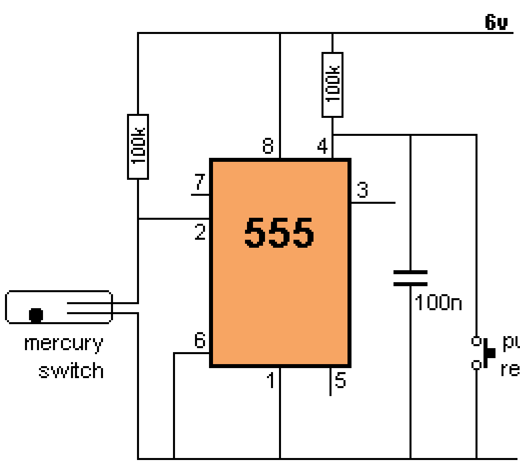


Dr CLARK'S ZAPPER



TILT SWITCH

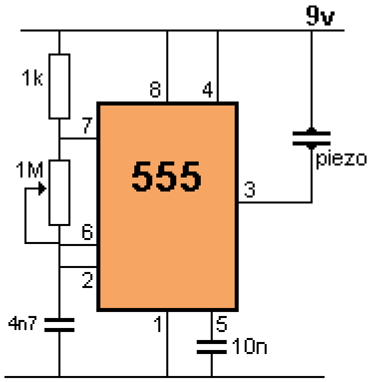
The output is LOW at start-up due to the capacitor on pin 4. When the mercury switch closes, the output goes HIGH and remains HIGH until the reset button is pressed. This circuit is called a LATCH. See Latch circuit and Memory Cell above.



TILT SWITCH

MOSQUITO REPELLER

This circuit produces a tone above the human audible range and this is supposed to keep the mosquitoes away. You need a piezo diaphragm that will respond to 15kHz and these are very difficult to find.



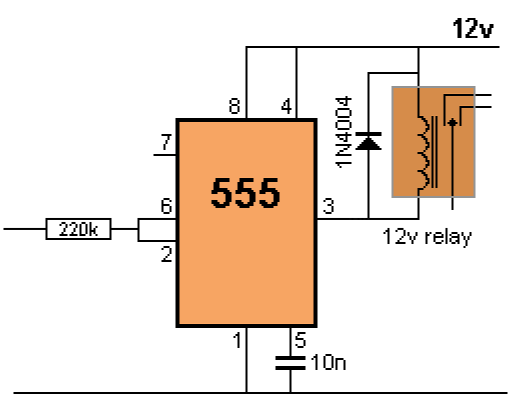
MOSQUITO REPELLENT

DRIVING A RELAY

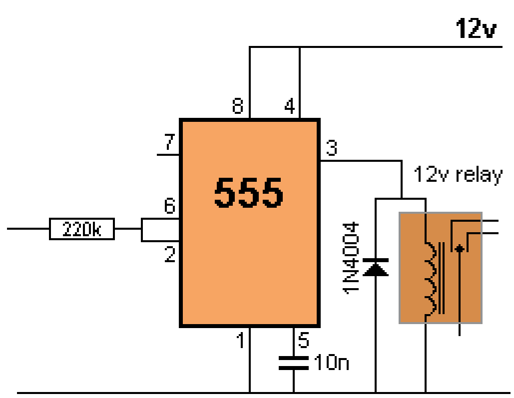
The 555 will activate a relay. When pins 2 and 6 are connected as an input, the chip requires only about 1uA to activate the output. This is equivalent to a gain of about 200,000,000 (200 million) and represents about 4 stages of amplification via transistors.
In the first circuit, the output will be opposite to the input. The relay can be connected "high" or "low" as show in the second diagram. One point to note: The input must be higher than 2/3V for the output to be low and below 1/3V for the output to be high. This is called HYSTERESIS and prevents any noise on the input creating "relay chatter."

THE DIODE

The diode across the relay is very important. It prevents spikes entering the 555 via pin3 but it also has an effect on the way the chip works.
In an experiment that activated the relay at 5Hz, the frequency changed to 2Hz when the diode was added. Somehow the noise entering the chip had an effect on the frequency.
The diode also improved the output waveform, as you would expect.



DRIVING A RELAY



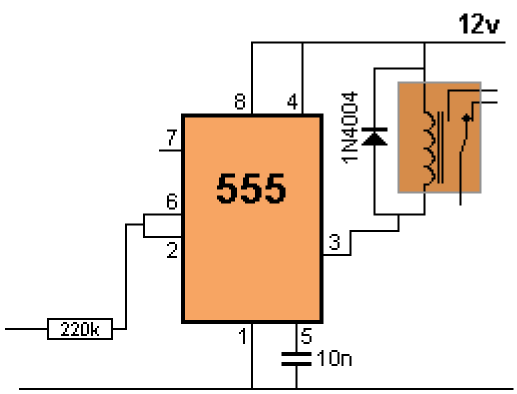
DRIVING A RELAY

NEGATIVE LOGIC

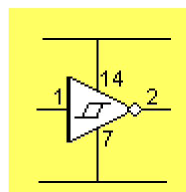
An interesting point to remember.
In the first diagram above, the relay is connected so that it is active when the output is low. This is called NEGATIVE or NEGATIVE LOGIC. It has the same reasoning as **-5 - (-5) = 0.**
Or in English: "I am not NOT going."
When the input is low in the first diagram, the output is HIGH and the relay is OFF. The circuitry creates two reversals and makes it easy to see that when the input is LOW, the relay is OFF.

SCHMITT TRIGGER (Hysteresis) also called AN INVERTER also called A SCHMITT INVERTER

This circuit is the same as **Driving A Relay** circuit above. It is the same circuit with a different name.
We have also animated the circuit to show how the output goes high or low according to the input level. The animation shows a wide gap between the input levels when the time when the output goes HIGH or LOW and this gap is called the HYSTERESIS GAP.
This circuit is called a SCHMITT TRIGGER and it is used in many building-blocks (using a different chip - such as 74c14) to prevent false triggering.
It prevents false triggering because as the input rises, the output does not change until the input voltage is fairly high. If the input voltage falls, the output does not change until the input falls about 30%. This means small fluctuations (noise) on the input do not have any effect on the output. The output is the INVERSE of the input - in other words the 555 is a SCHMITT INVERTER. The second diagram shows a Schmitt Trigger building block.



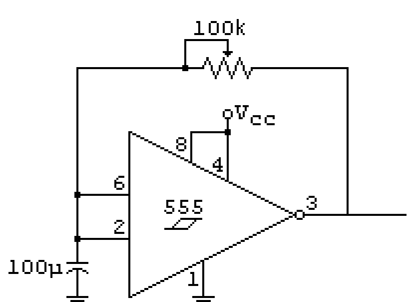
DRIVING A RELAY



SCHMITT TRIGGER BUILDING BLOCK

THE 555 AS A SCHMITT TRIGGER

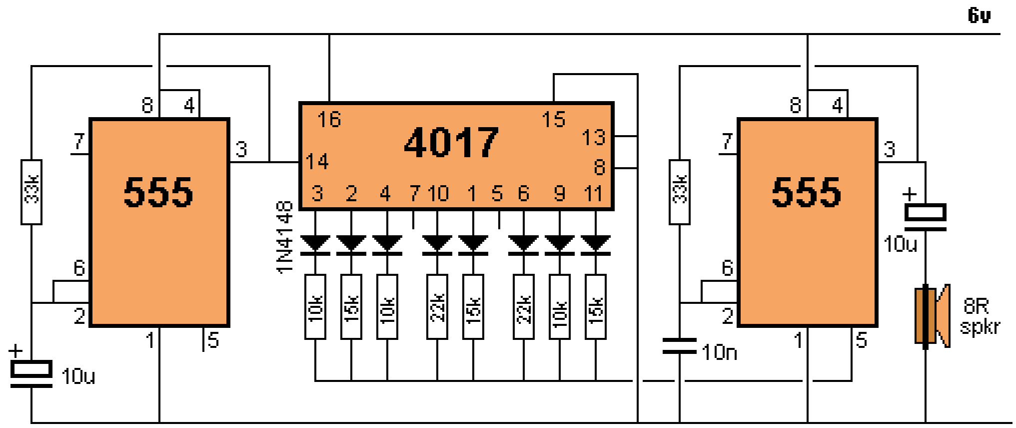
Here is another way to "see" a 555.
The 555 is drawn as a SCHMITT TRIGGER.
The 555 is actually a SCHMITT TRIGGER when pin 2 and 6 are connected together and pin 3 is take to the join of these pins.



Pin 2 detects 33% of rail voltage on the electrolytic to turn the 555 ON and pin 6 detects 66% of rail voltage on the 100u to turn the 555 OFF.
The IC can also drive a LOAD with about 200mA and it can either source or sink the 200mA, so the chip is quite versatile.

MUSIC BOX

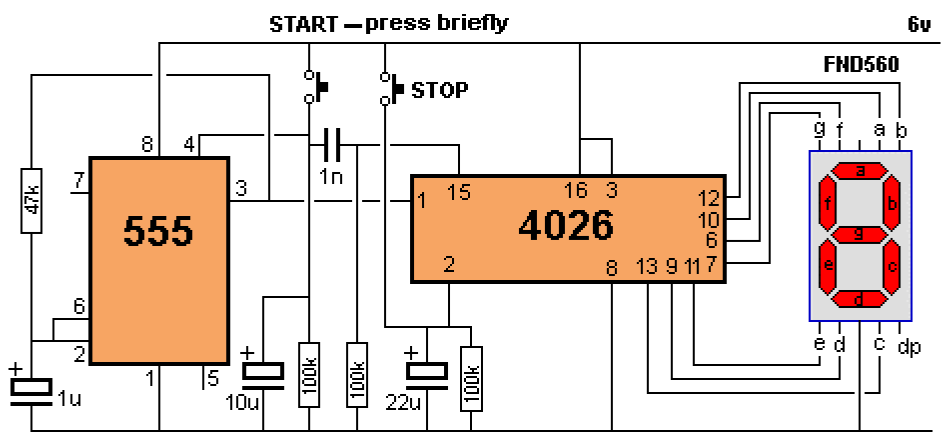
This circuit produces 10 different tones and by selecting suitable values to change the voltage on pin 5, the result can be quite pleasing. Note: the two unused outputs of the 4017 produce a tone equal to that produced by the 555 when pin 5 has no external control voltage.



MUSIC BOX

REACTION TIMER GAME

This is a game for two players.
Player 1 presses the **START** button. This resets the 4026 counter chip and starts the 555 oscillator.
The 555 produces 10 pulses per second and these are counted by the 4026 chip and displayed on the 7-Segment display.
The second player is required to press the **STOP** button. This freezes the display by activating the **Clock Inhibit** line of the 4026 (pin 2).
Two time-delay circuits are included. The first activates the 555 by charging a 10u electrolytic and at the same time delivering a (high) pulse to the 4026 chip to reset it.
The second timer freezes the count on the display (by raising the voltage on pin 2) so it can be read.

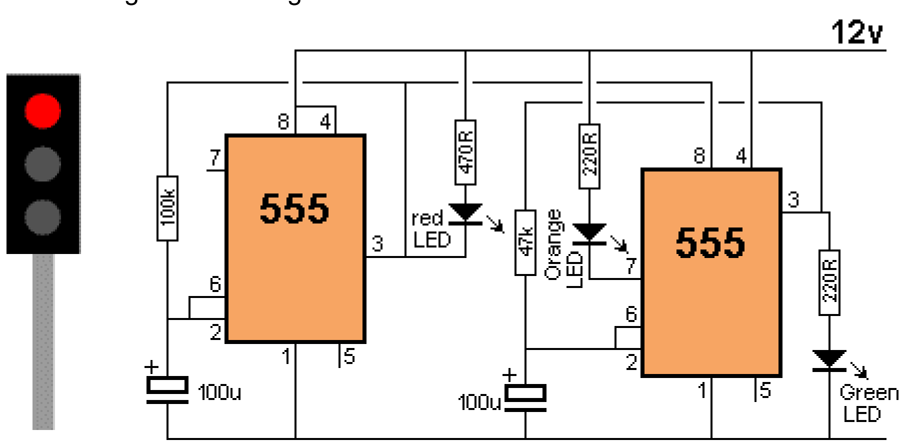


REACTION TIMER

Prototype produced by Bruce Pierson
see: Bruce Pierson website for PCB layout

TRAFFIC LIGHTS

Here's a clever circuit using two 555's to produce a set of traffic lights for a model layout.
The animation shows the lighting sequence and this follows the Australian-standard.
The red LED has an equal on-off period and when it is off, the first 555 delivers power to the second 555. This illuminates the Green LED and then the second 555 changes state to turn off the Green LED and turn on the Orange LED for a short period of time before the first 555 changes state to turn off the second 555 and turn on the red LED.
A supply voltage of 9v to 12v is needed because the second 555 receives a supply of about 2v less than rail. This circuit also shows how to connect LEDs high and low to a 555 and also turn off the 555 by controlling the supply to pin 8. Connecting the LEDs high and low to pin 3 will not work and since pin 7 is in phase with pin 3, it can be used to advantage in this design.



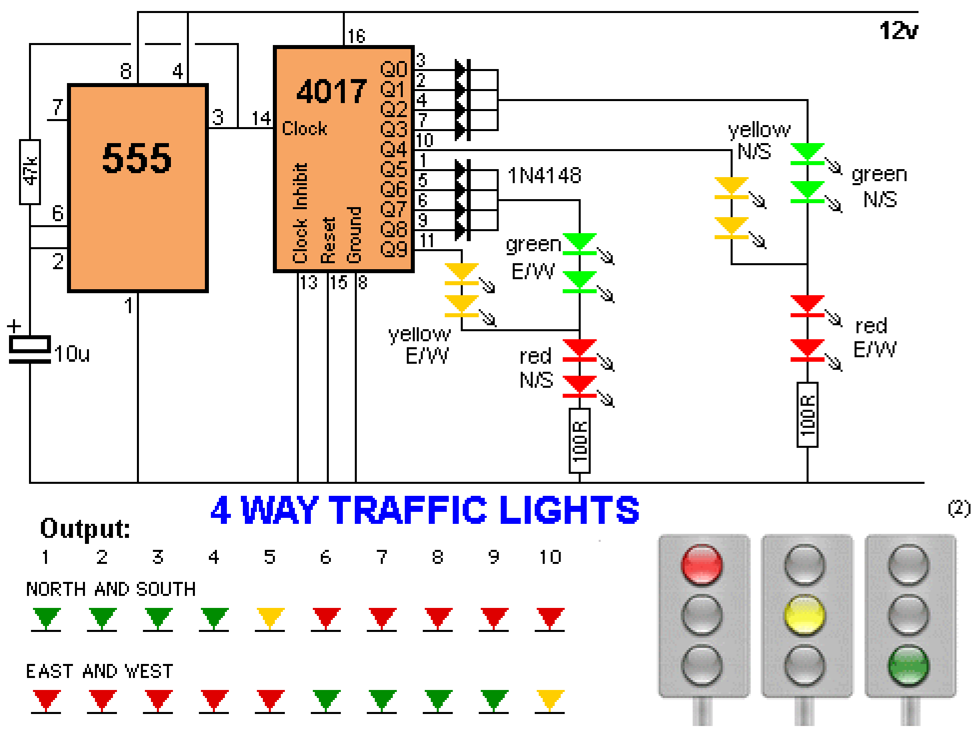
TRAFFIC LIGHTS

Here is a further description of how the circuit works:
Both 555's are wired as oscillators in astable mode and will oscillate ALL THE TIME when they are turned ON. But the second 555 is not turned on all the time!
The first 555 turns on and the 100u is not charged. This makes output pin 3 HIGH and the red LED is not illuminated. However the output feeds the second 555 and it turns on.
Output pin 3 of the second 555 turns on the green LED and the second 100u charges to 2/3 rail voltage and causes the 555 to change states. The green LED goes off and the orange LED turns on.
The second 100u starts to discharge, but the first 100u is charging via a 100k and after the orange LED has been on for a short period of time, the first 555 changes

state and pin 3 goes LOW.
This turns on the red LED and turns off the second 555.
The first 100u starts to discharge via the 100k and eventually it changes state to start the cycle again.
The secret of the timing is the long cycle-time of the first 555 due to the 100k and the short cycle due to the 47k on the second 555.
One problem is the timing for the first time the circuit is turned ON is different to the continued operation, because the 100u's have to charge from 0v.
The sequence was not perfect with 100u + 100u so Paul Mathew changed the first 100u to 220u and the sequence was perfect.
You can change the 100k to 220k instead of changing the electrolytic.

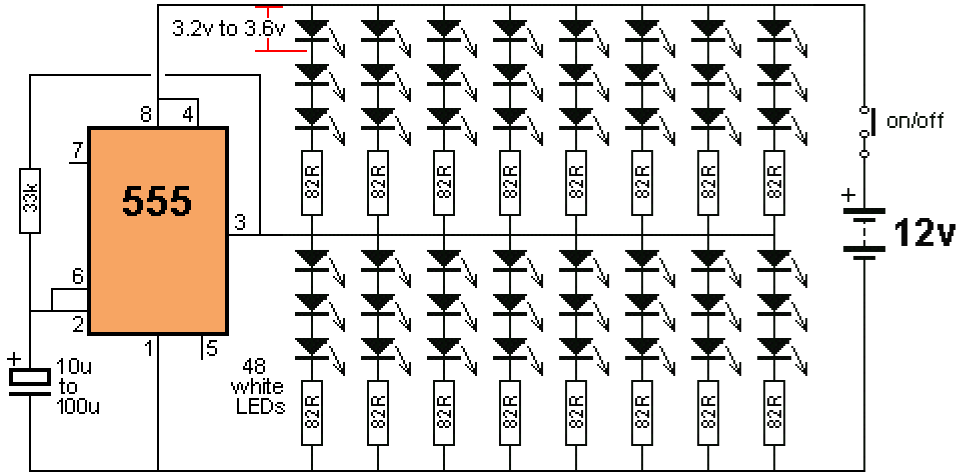
4 WAY TRAFFIC LIGHTS

This circuit produces traffic lights for a "4-way" intersection. The seemingly complex wiring to illuminate the lights is shown to be very simple.



DRIVING MANY LEDS

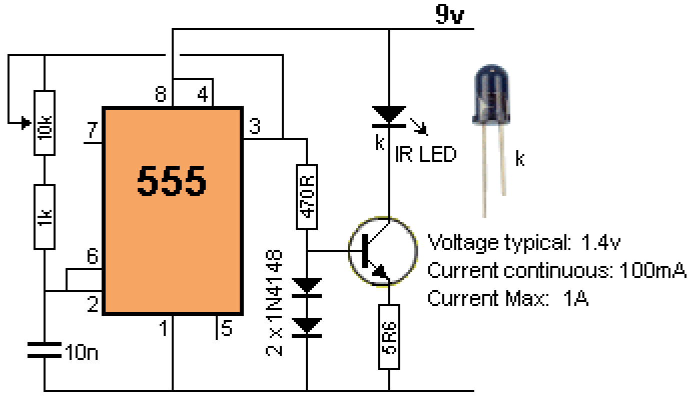
The 555 is capable of sinking and sourcing up to 200mA, but it gets very hot when doing this on a 12v supply.
The following circuit shows the maximum number of white LEDs that can be realistically driven from a 555 and we have limited the total current to about 130mA as each LED is designed to pass about 17mA to 22mA maximum. A white LED drops a characteristic 3.2v to 3.6v and this means only 3 LEDs can be placed in series.



DRIVING WHITE LEDS (FLASHING)

TV REMOTE CONTROL JAMMER

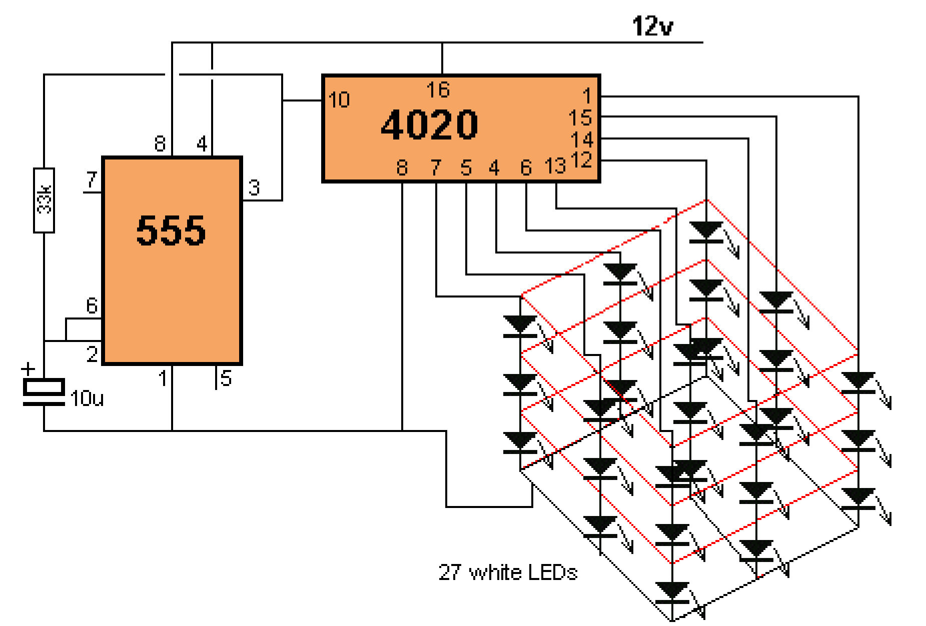
This circuit confuses the infra-red receiver in a TV. It produces a constant signal that interferes with the signal from a remote control and prevents the TV detecting a channel-change or any other command. This allows you to watch your own program without anyone changing the channel !! The circuit is adjusted to produce a 38kHz signal. The IR diode is called an Infra-red transmitting Diode or IR emitter diode to distinguish it from a receiving diode, called an IR receiver or IR receiving diode. (A **Photo diode** is a receiving diode). There are so many IR emitters that we cannot put a generic number on the circuit to represent the type of diode. Some types include: CY85G, LD271, CQY37N(45¢), INF3850, INF3880, INF3940 (30¢). The current through the IR LED is limited to 100mA by the inclusion of the two 1N4148 diodes, as these form a constant-current arrangement when combined with the transistor and 5R6 resistor.

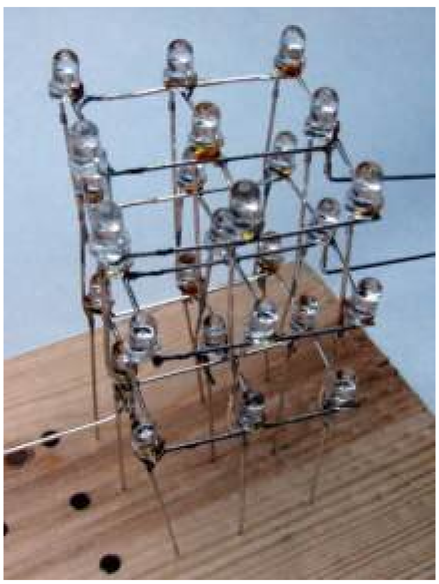


TV REMOTE JAMMER

3x3x3 CUBE

This circuit drives a 3x3x3 cube consisting of 27 white LEDs. The 4020 IC is a 14 stage binary counter and we have used 9 outputs. Each output drives 3 white LEDs in series and we have omitted a dropper resistor as the chip can only deliver a maximum of 15mA per output. The 4020 produces 512 different patterns before the sequence repeats and you have to build the project to see the effects it produces on the 3D cube.

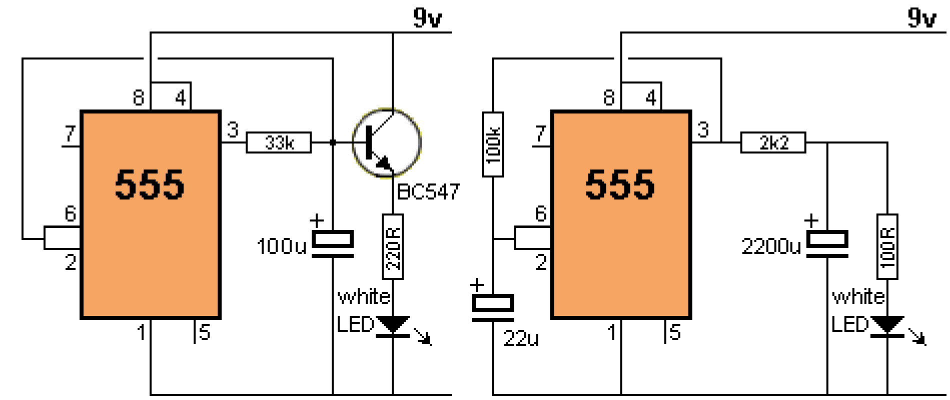




If you are having trouble understanding the circuit, here is a guide:
There are 9 strings of 3 LEDs.
Here is how to solder them together:
Connect 3 LEDs together and do this 9 times.
Now connect the cathode of the end of each string to all the other strings.
Now you have 9 strings of LEDs all connected together at the bottom.
Connect the top of each string to one of the pins: 7, 5, 4, 6, 13, 12, 14, 15, 1.
Now connect all the cathodes (they are already connected together) to pins 1 and 8 of the chips.
A 47R resistor can be connected to each of the outputs to limit the current if you are increasing the supply above 12v.

UP/DOWN FADING LED

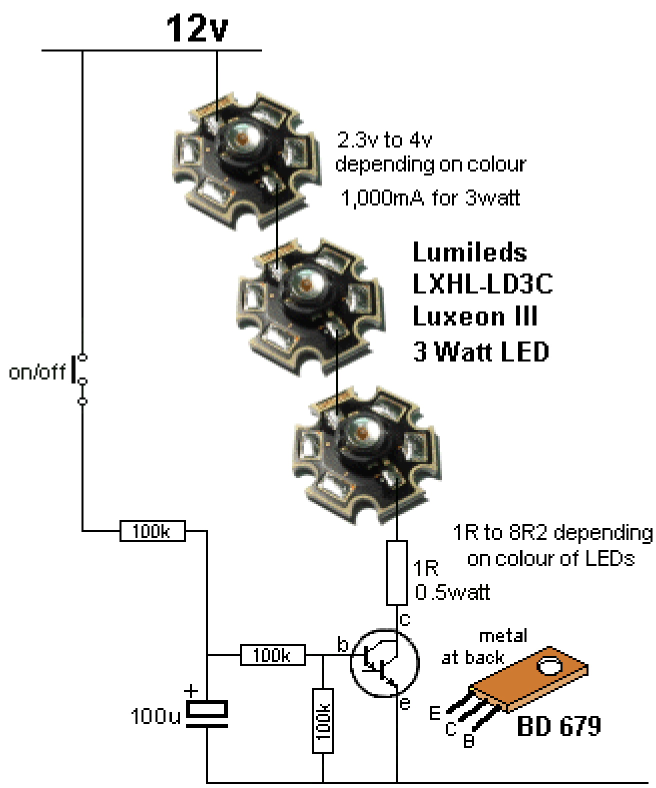
These two circuits make a LED fade on and off. The first circuit charges a 100u and the transistor amplifies the current entering the 100u and delivers 100 times this value to the LED via the collector-emitter pins. The circuit needs 9v for operation since pin 2 of the 555 detects 2/3Vcc before changing the state of the output so we only have a maximum of 5.5v via a 220R resistor to illuminate the LED. The second circuit requires a very high value electrolytic to produce the same effect.



UP/ DOWN FADING LED

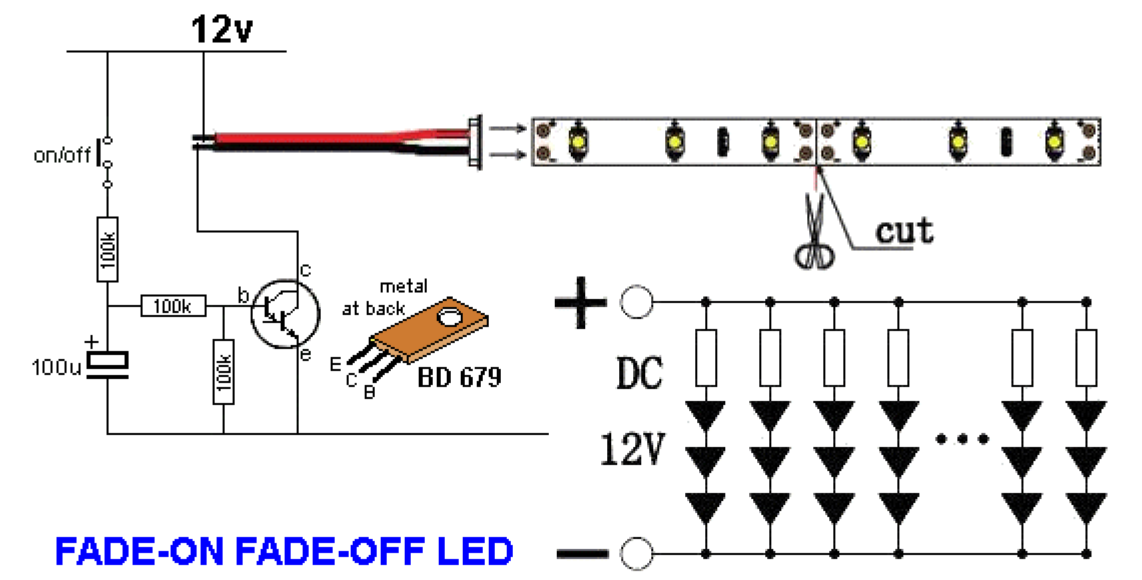
These circuits will really only support one LED. One constructor tried two LEDs and it did not work.
Here's the reason: The transistor amplifies the energy that the 100u is able to deliver on each cycle and this is only enough for one LED. Similarly, the 2,200u is only able to supply energy to one LED.
It works like this: The transistor detects the amount of current the LED wants at any part of the cycle (due to its illumination) and it takes about one-hundredth or one two-hundredth of this from the electrolytic. 99% of the current is delivered via the collector (via the supply rail). If two LEDs are connected, the electrolytic cannot supply the extra energy and the circuit may not work.
The energy in the 100u is supplied by the 33k and if you want it to deliver more energy, the 33k will have to be reduced.

f you just want fade-ON and fade-OFF, this circuit is all you need:



FADE-ON FADE-OFF LED

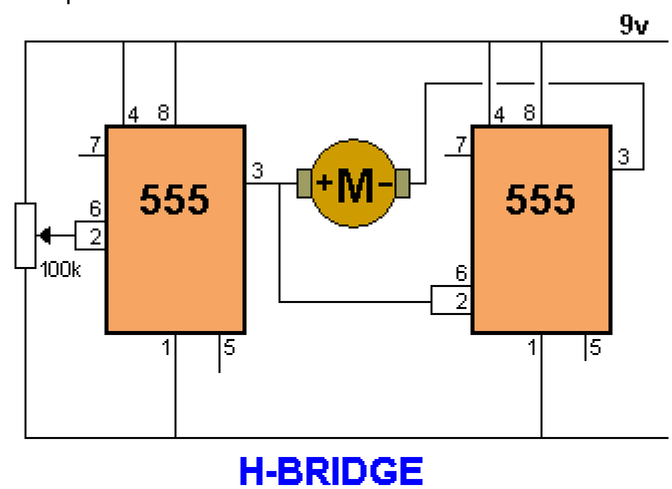
You can also drive "rope lights."
These can be surface-mount LEDs or totally-sealed LEDs and generally have two wires connected to one end for the 12v supply.
Three LEDs are generally connected in series inside the "rope" with a dropper resistor and some "ropes" can be cut after each set of three LEDs as shown in the diagram below:



Each set of three LEDs draws about 20mA so a rope of 24 LEDs takes about 160mA. Adjust the first two 100k resistors and 100u to set the fade-IN and fade-OUT feature.

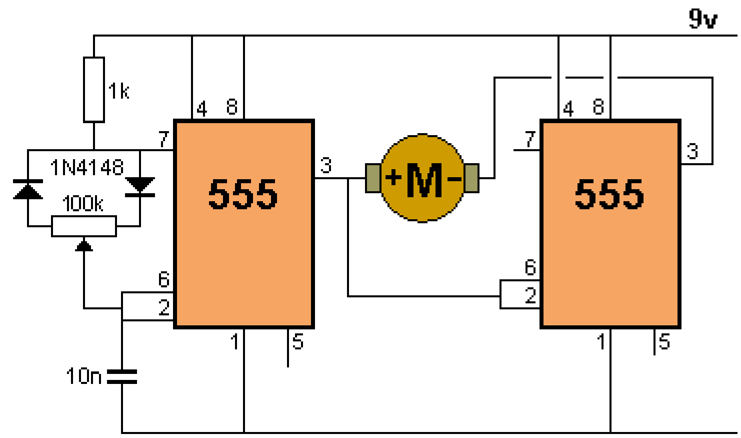
H-BRIDGE

This circuit drives a motor clockwise / anticlockwise via a 10k to 100k pot.



H-BRIDGE WITH PWM

This circuit drives a motor clockwise / anticlockwise via a pot and reduces the speed to zero when the pot is in mid-position. The current is limited to 200mA and the voltage across the motor is less than 6v, but the circuit shows the principle of Pulse Width Modulation (providing powerful bursts of current to the motor to create a high or low RPM under load) and both forward / reverse RPM via the H-bridge arrangement.

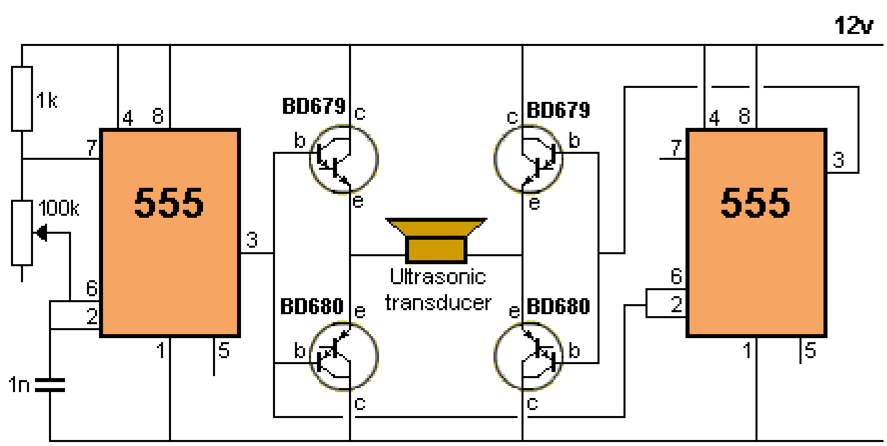


H-BRIDGE WITH PWM

H-BRIDGE PUSH-PULL DOG-BARK STOPPER

The two circuits above are also **H-Bridge Push-Pull** outputs, however the current is limited to 200mA or less. In this design the current can be 3 amps or more, depending on the supply voltage, the resistance of the load and the type of driver transistors. About 2v5 is lost between "c and e" due to the output of the 555 and the base-emitter voltage of the driver transistors. This circuit drives an ultrasonic transducer (speaker) at 20kHz to 40kHz to subdue dog barking.
If the unit is turned on by remote control every time the dog barks, the animal will soon learn to cease barking.

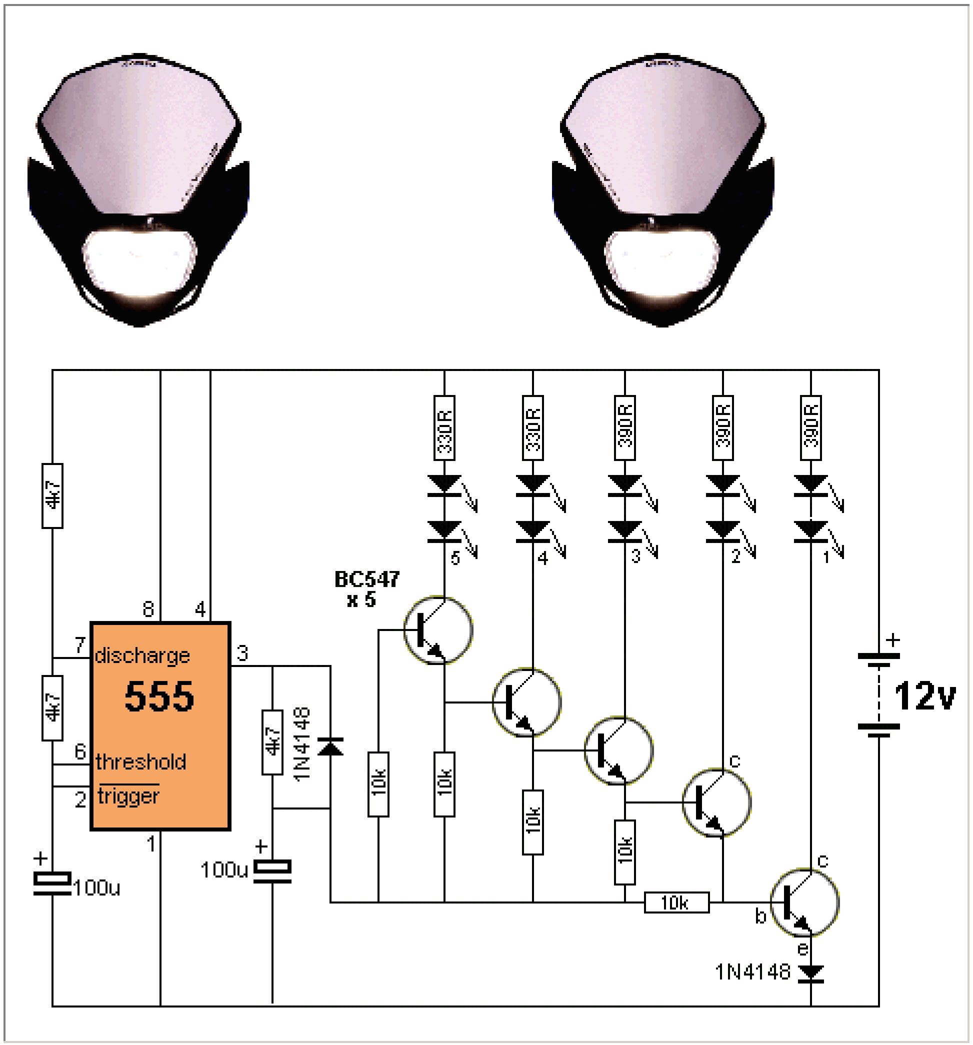
Look on eBay for Piezo Tweeter for about $3.00 plus $7.00 postage. The maximum frequency response will be about 30kHz.



H-BRIDGE PUSH-PULL

BIKE TURNING SIGNAL

This circuit can be used to indicate left and right turn on a motor-bike. Two identical circuits will be needed, one for left and one for right.

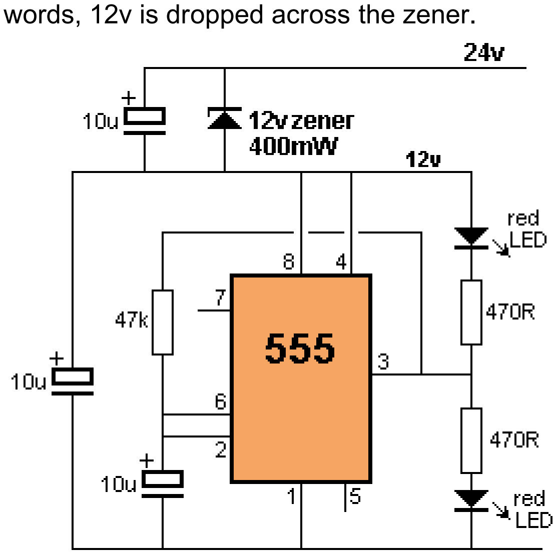


555 ON 24v

If you need to operate a 555 on 24v, you will need to reduce the voltage to less than 18v. The following circuits reduce the voltage to 12v:

30mA:

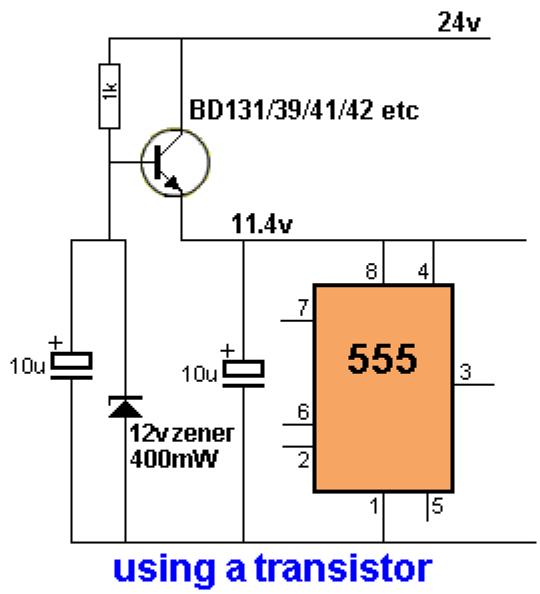
If the 555 circuit takes less than 30mA (the 555 takes 10mA) you can use a 400mW zener diode to drop the 24v supply to 12v for the 555. In other words, 12v is dropped across the zener.



FLASHING LEDs

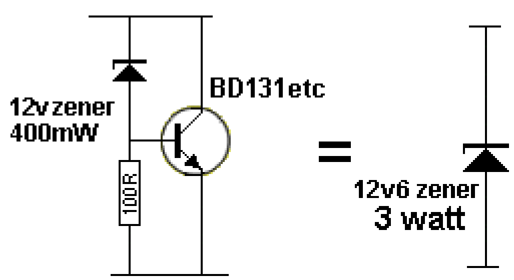
Up to 500mA:

The next circuit will allow up to 500mA. The transistor will need to be placed on a large heatsink. It is an emitter-follower-regulator transistor and can be used with a 400mW zener. The output voltage is 0.6v lower than the zener voltage.



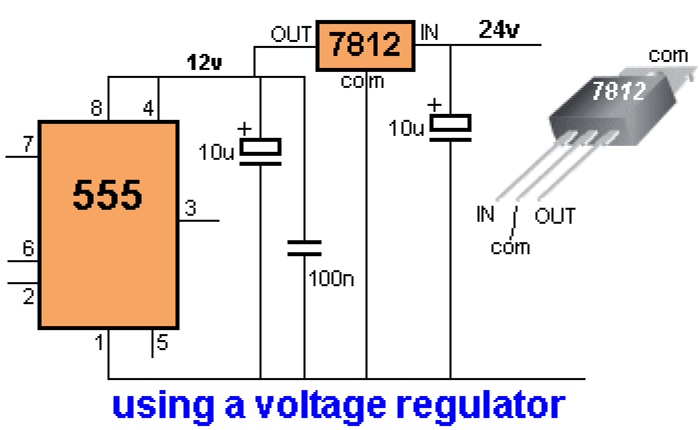
Up to 500mA with "Amplifier Zener"

A 400mW zener can be converted to a "Power Zener" by combining with a transistor as shown in the following circuit: 12.6v will be dropped across the rails. In other words, if the top rail is 24v, the bottom rail will be 11.4v.



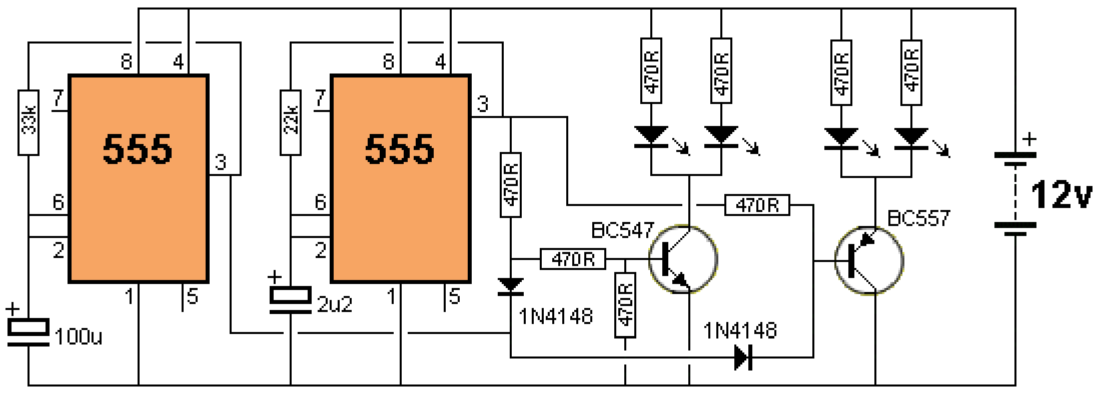
Up to 1A:

Using the next circuit will allow the 555 to take 200mA and the load to take 800mA. The 7812 will need to be placed on a large heatsink. The 7812 is called a 3-terminal VOLTAGE REGULATOR.

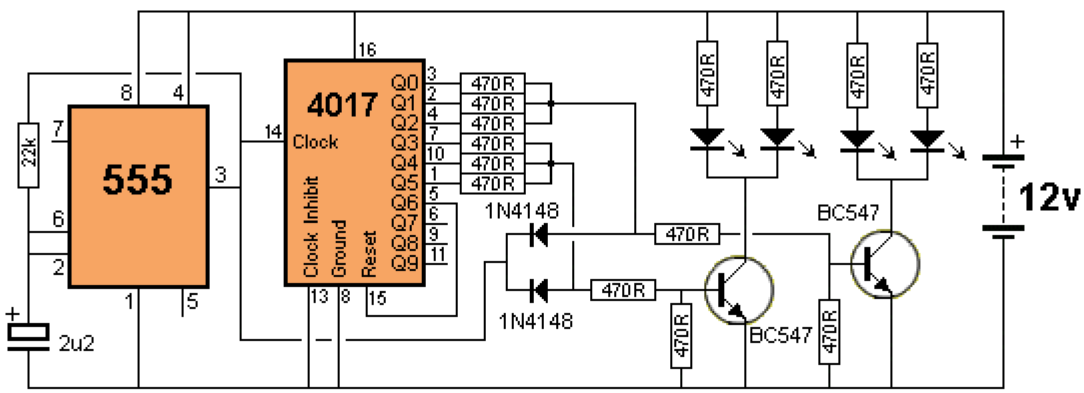


POLICE LIGHTS

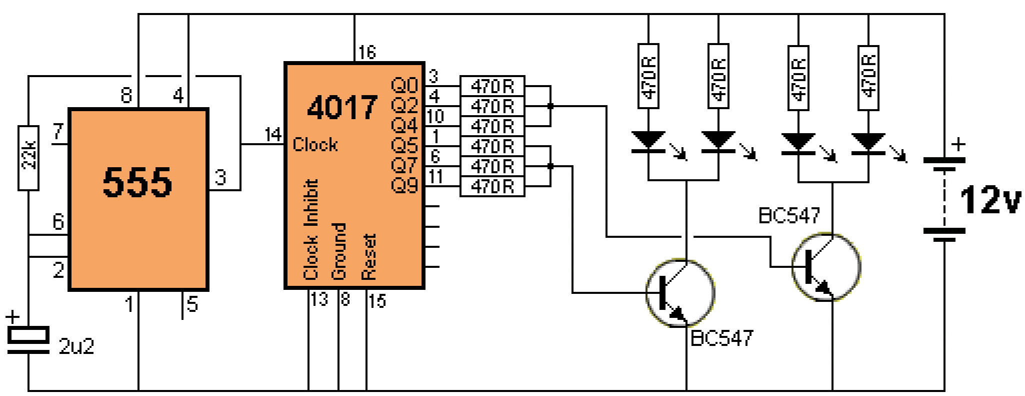
These three circuits flash the left LEDs 3 times then the right LEDs 3 times, then repeats. The only difference is the choice of chips.



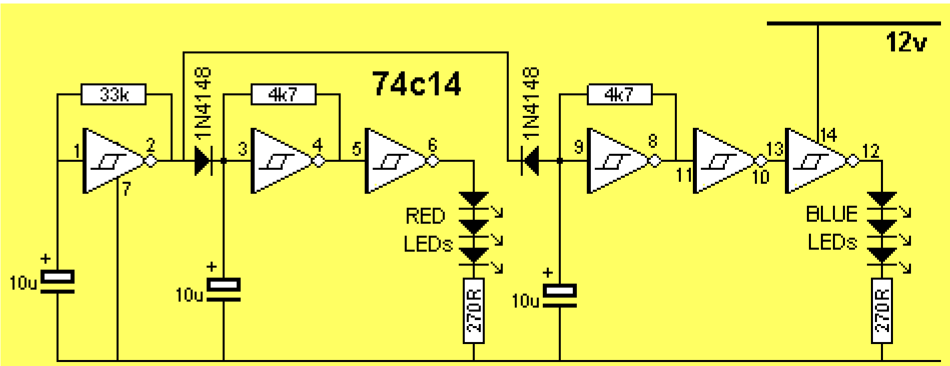
POLICE LIGHTS



POLICE LIGHTS - 2



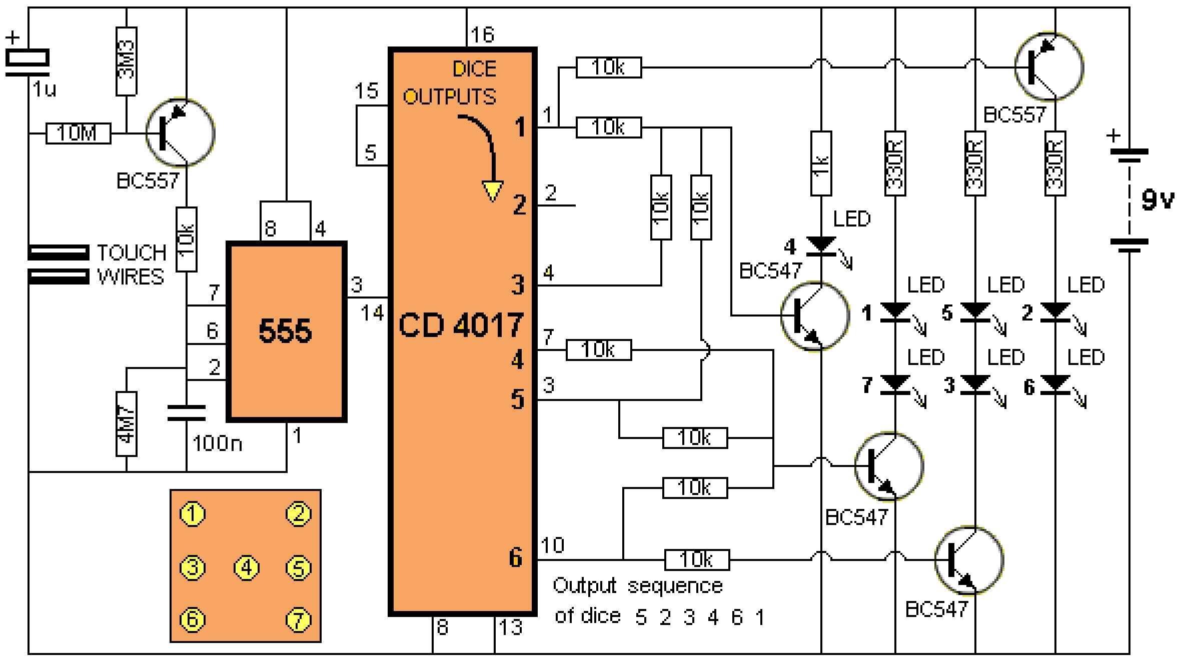
POLICE LIGHTS - 2a



POLICE LIGHTS-3

LED DICE with Slow Down

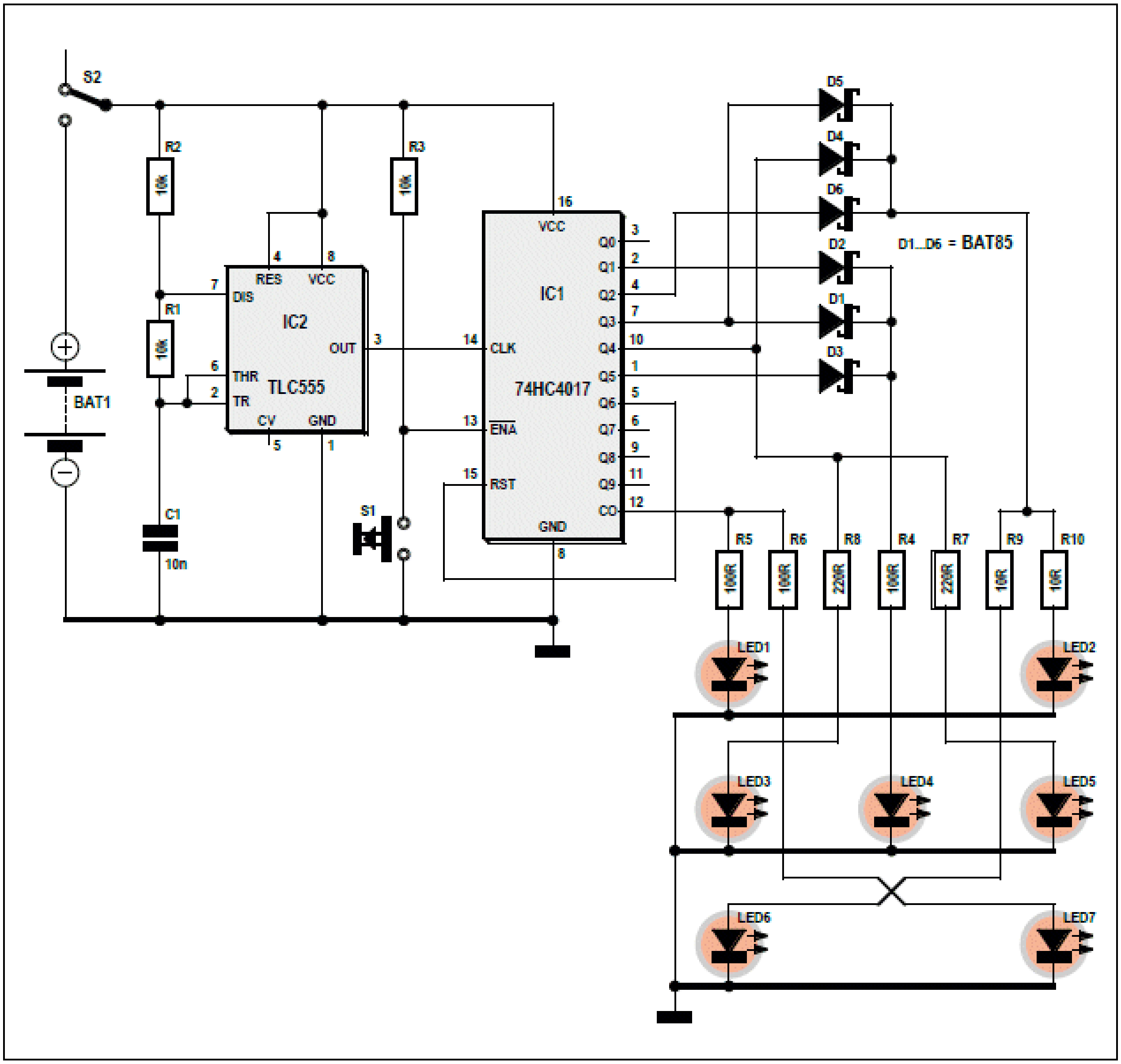
This circuit produces a random number from 1 to 6 on LEDs that are similar to the pips on the side of a dice. When the two TOUCH WIRES are touched with a finger, the LEDs flash very quickly and when the finger is removed, they gradually slow down and come to a stop. **LED Dice with Slow Down kit** is available from Talking Electronics.



The **LED Dice with Slow Down kit** is available for $16.00 plus $6.50 postage.
The kit includes the parts and PC board.

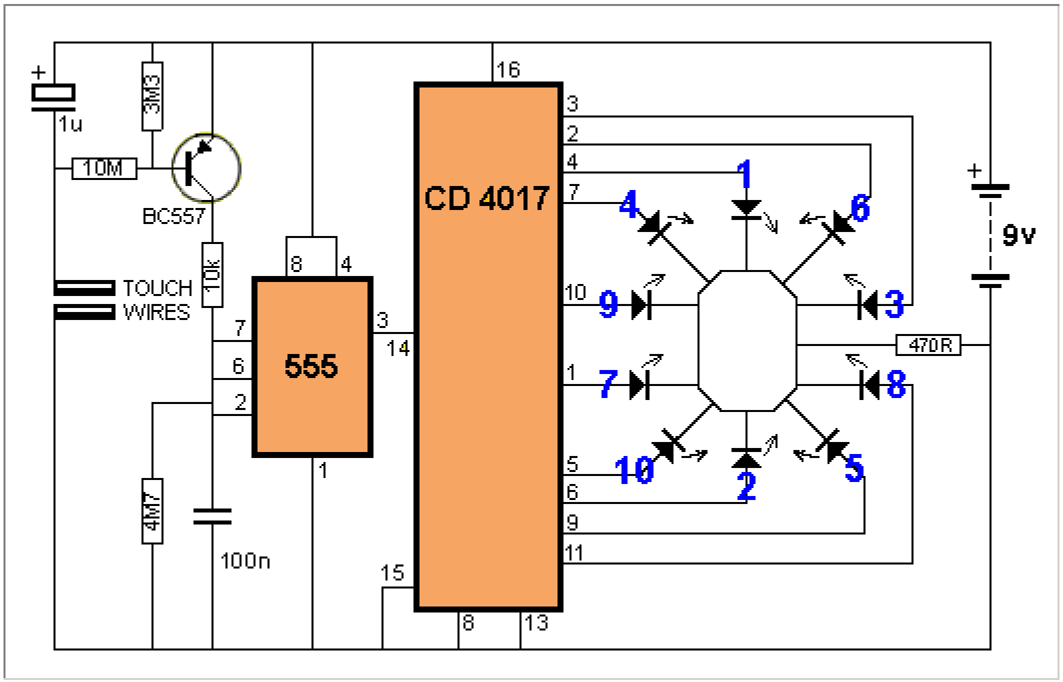
LED DICE-3

This circuit creates a rotating LED that starts very fast when a finger touches the TOUCH WIRES. When the finger is removed, the rotation slows down and finally stops.



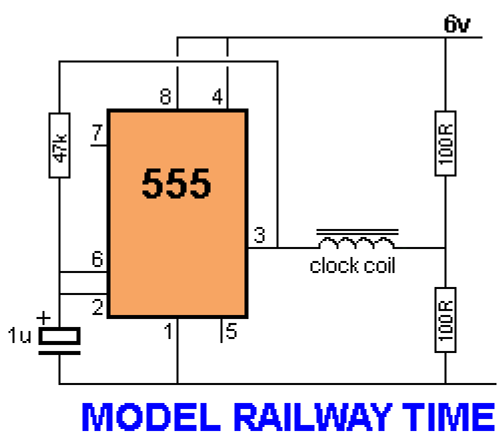
ROULETTE

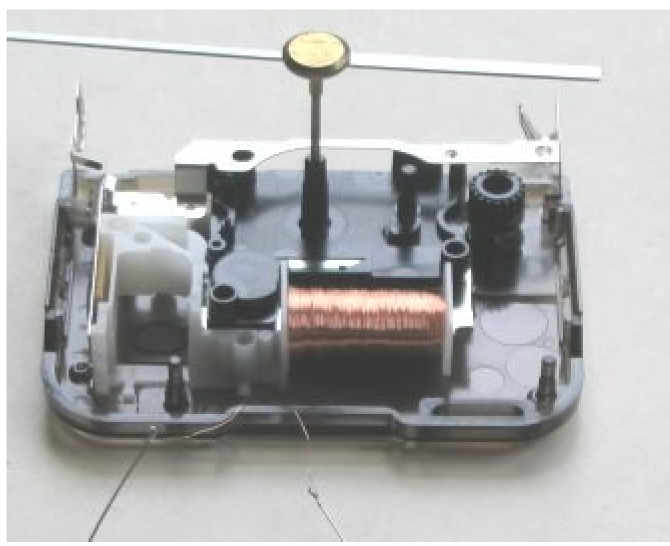
This circuit creates a rotating LED that starts very fast when a finger touches the TOUCH WIRES. When the finger is removed, the rotation slows down and finally stops.



MODEL RAILWAY TIME

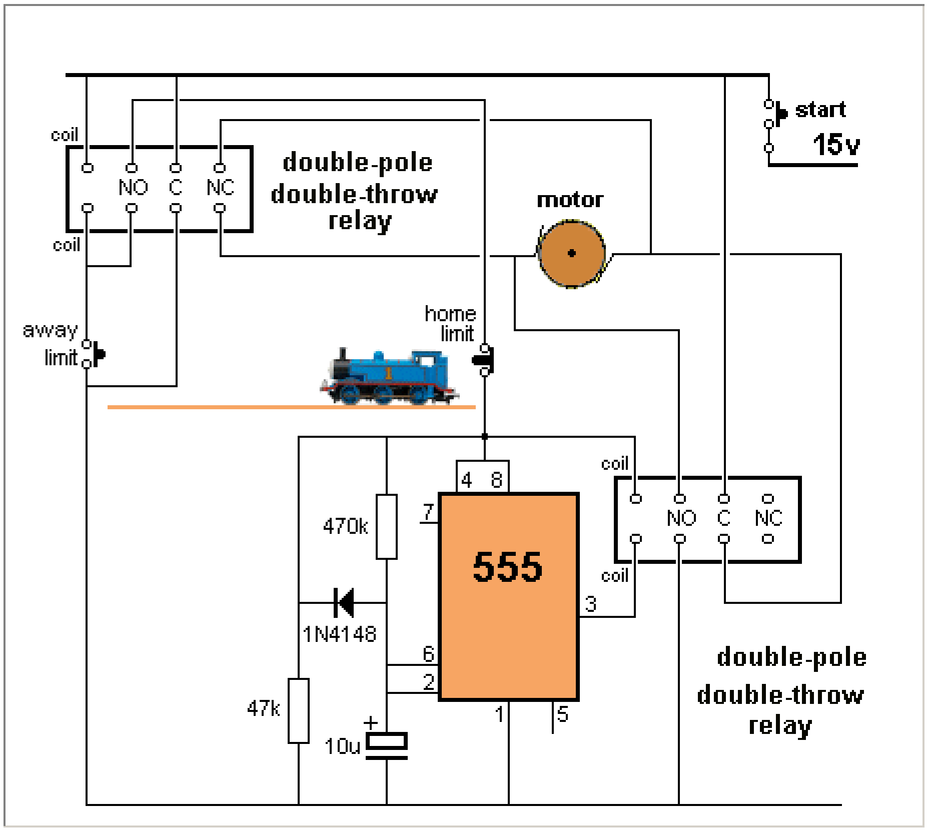
Here is a circuit that will convert any clock mechanism into Model Railway Time.
For those who enjoy model railways, the ultimate is to have a fast clock to match the scale of the layout. This circuit will appear to "make time fly" by turning the seconds hand once every 6 seconds. The timing can be adjusted by changing the 47k. The electronics in the clock is disconnected from the coil and the circuit drives the coil directly. The circuit takes a lot more current than the original clock (1,000 times more) but this is one way to do the job without a sophisticated chip.





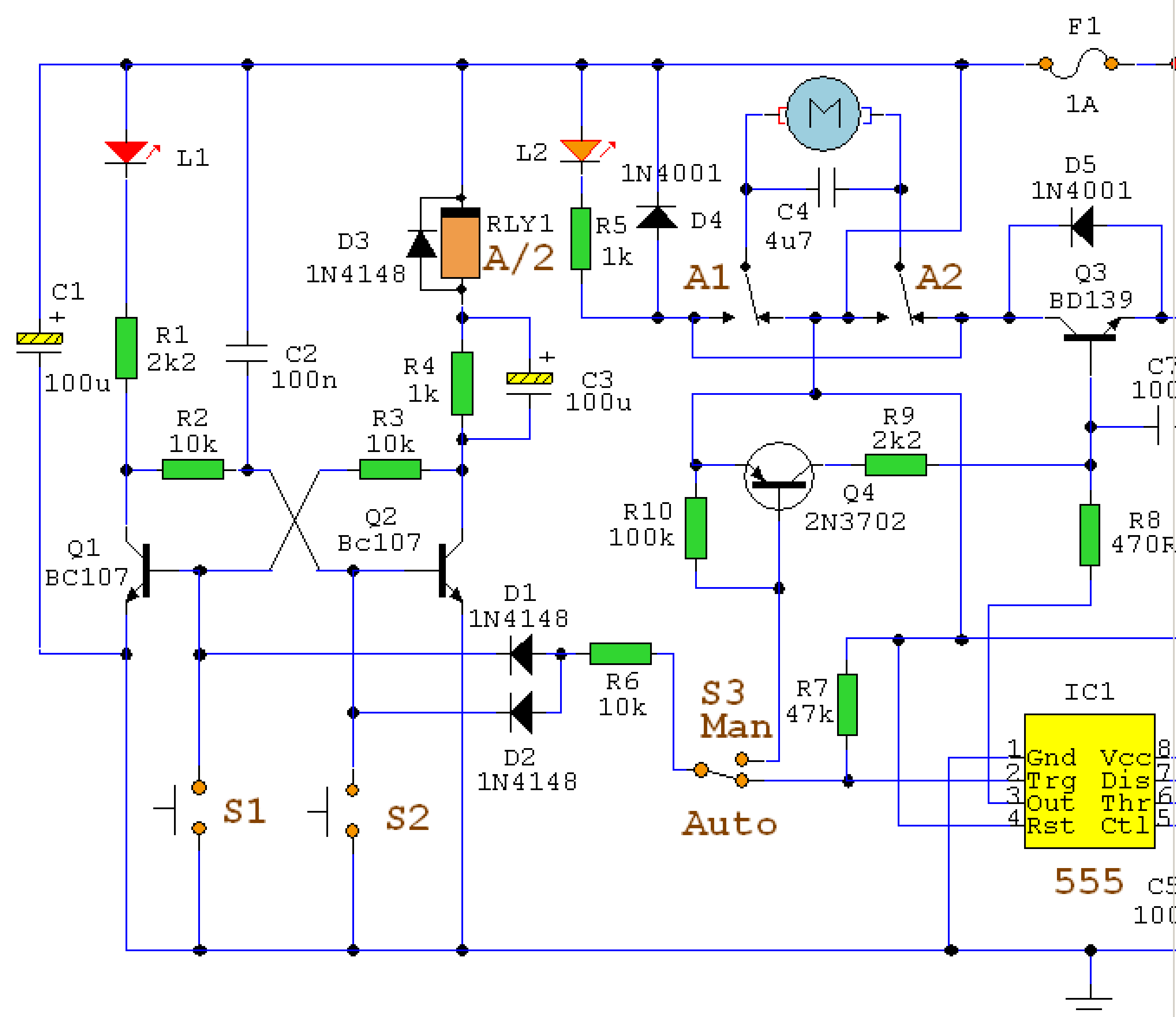
REVERSING A MOTOR-4 (see 1, 2, 3 in 200 Transistor Circuits)

In this example the power is applied via the start switch and the train moves to the away limit switch and stops. The 555 creates a delay of 1 minute and the train moves to the home limit and stops. Turn the power on-off to restart the action.



AUTOMATIC CURTAIN CLOSER

Circuit : Andy Collinson
Email: anc@mitedu.freeserve.co.uk



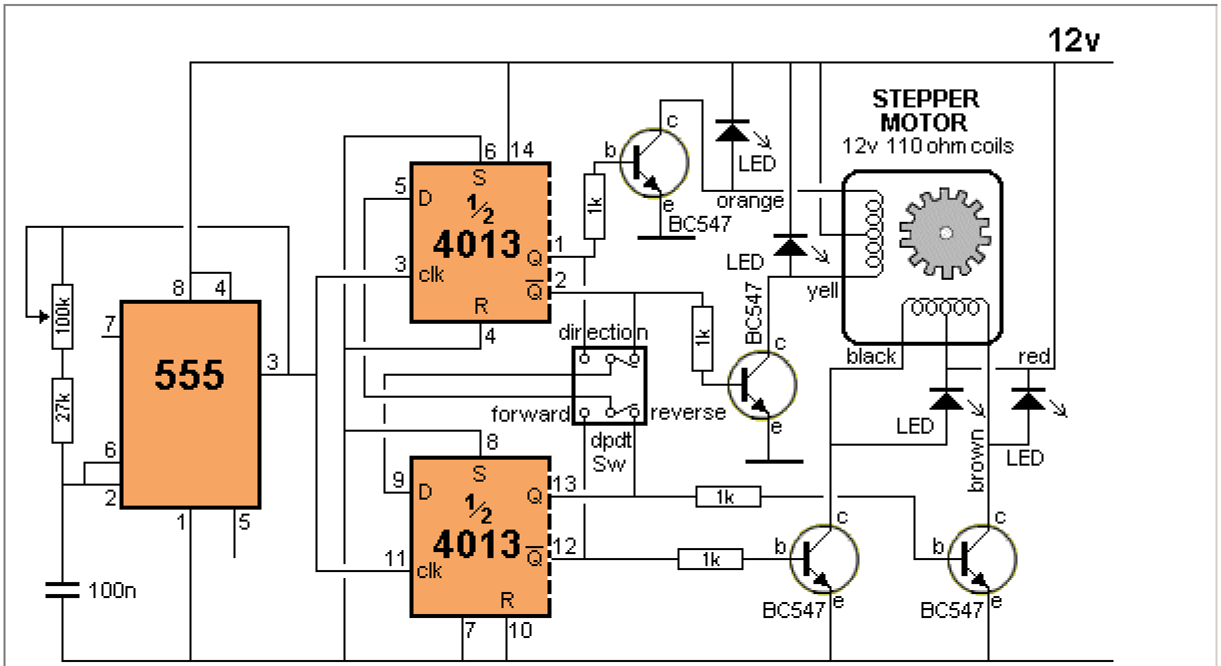
This circuit uses a mixture of transistors, an IC and a relay and is used to automatically open and close a pair of curtains. Using switch S3 also allows manual control, allowing curtains to be left only partially open or closed. The circuit controls a motor that is attached to a simple pulley mechanism, to move the curtains.

Automatic Operation

The circuit can be broken into three main parts; a bi-stable latch, a timer and a reversing circuit. Toggle switch S3 determines manual or automatic mode. The circuit as shown above is drawn in the automatic position and operation is as follows. The bi-stable is built around Q1 and Q2 and associated circuitry and controls relay A/2. S1 is used to open the curtains and S2 to close the curtains. At power on, a brief positive pulse is applied to the base of Q2 via C2. Q2 will be on, and activate relay A/2.

The network of C3 and R4 form a low current holding circuit for the relay. Relay A/2 is a 12V relay with a 500 ohm coil. It requires slightly less current to keep it energized than it does to operate it. Once the relay has operated, the current through the coil is reduced by R4, saving power consumption. When Q2 is off, C3 will be discharged, but when Q2 becomes active (either at switch-on or by pressing S1) capacitor C3 will charge very quickly via the relay coil. The initial charging current is sufficient to energize the relay and current flow through R4 sufficient to keep it energized.

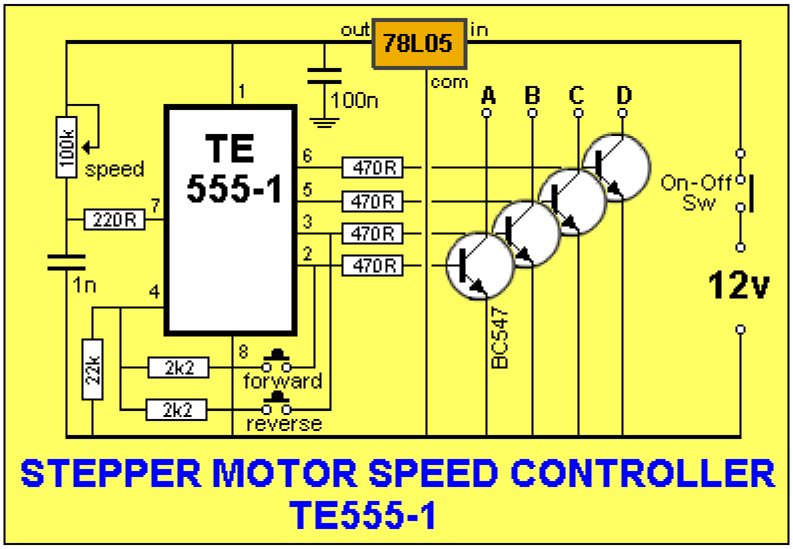
STEPPER MOTOR CONTROLLER

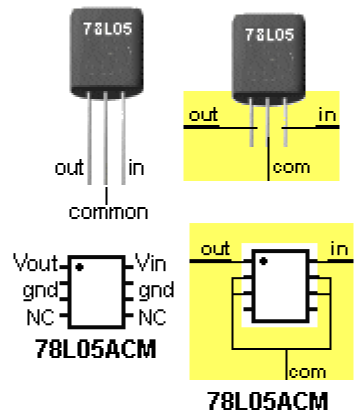


STEPPER MOTOR CONTROLLER

This circuit controls the speed of a stepper motor via the 100k pot. The direction of rotation is determined by the double-pole double-throw switch.
The stepper motor used in this circuit came from an old scanner. It had 5 wires: red-black-yellow-brown-orange. The LEDs illuminate via the back-emf of the coils and prevent the spikes entering the transistors. The LEDs will flicker to show the pulses being received by the stepper motor.
The 27k stop-resistor limits the upper-frequency of the 555 and prevents the circuit producing pulses that are too fast for the stepper motor.
If the colour coding is different on your stepper motor and it fails to work, you only need to reverse two connections thus:
A B C D
A B D C (reverse the two end connections) and if this fails,
A D B C (reverse the two middle connections)

This stepper motor costs less than $5.00 from BG Micro and has 6 wires as shown in the diagram above.

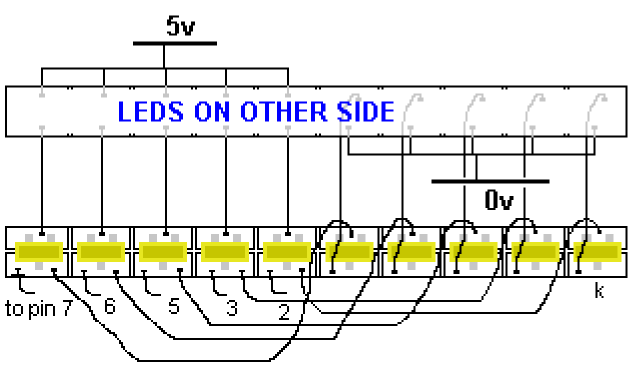




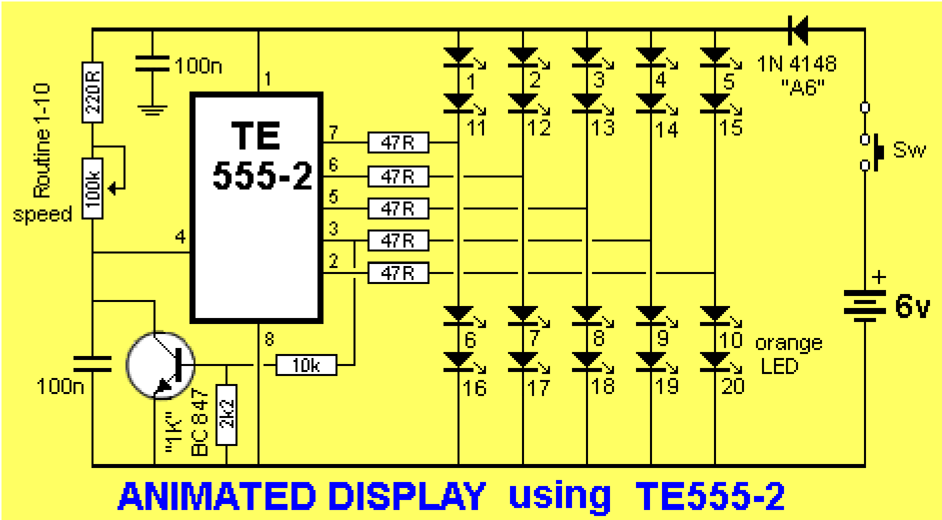
This circuit uses the latest [TE555-1] STEPPER MOTOR SPEED CONTROLLER chip from Talking Electronics. It is available for $2.50 and controls the speed of a stepper motor via the 100k pot. The direction of rotation is determined by the FORWARD and REVERSE switches and the motor does not take any current when a switch is not pressed.

ANIMATED DISPLAY CONTROLLER TE555-2

This circuit uses the latest [TE555-2] ANIMATED DISPLAY CONTROLLER chip from Talking Electronics. This 8-pin chip is available for $2.50 and produces 7 different animations on a 10 LED display. The animations are selected by the position of a 100k pot and when the animation is showing, the pot can be adjusted to increase the speed of the animation.
"Position 10" on the pot cycles through the 7 animations.

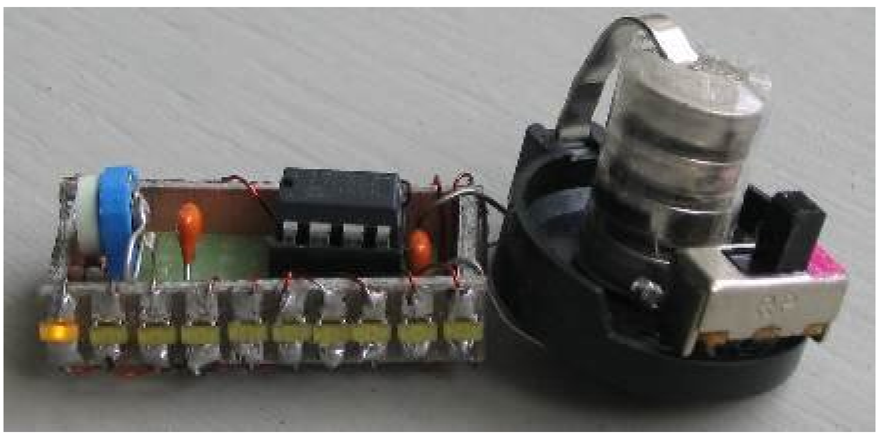


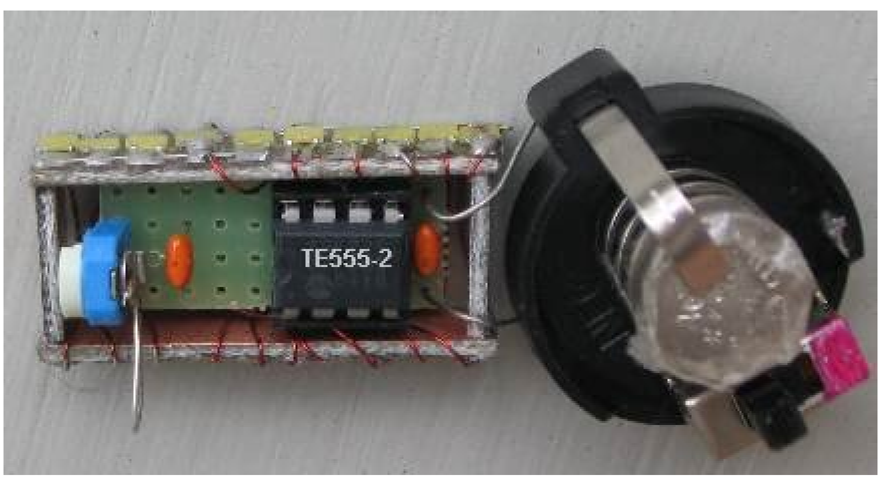
A kit of components (matrix board, PC board for LEDs, surface-mount resistors, capacitors, transistor, diode, switch, cells, battery holder, pot and 20 yellow LEDs with TE555-2 chip is available for $15.00 plus $5.00 postage. Click the link above and you will be sent an email with the costs. This is an ideal project you get you into



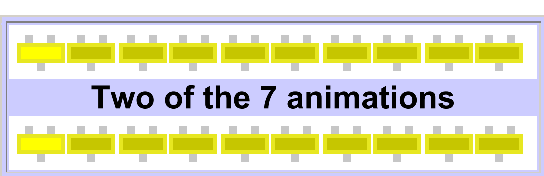
surface-mount technology and you can add it to a model layout or build it into a Lego brick for a junior member.

Wiring the two ten-LED displays



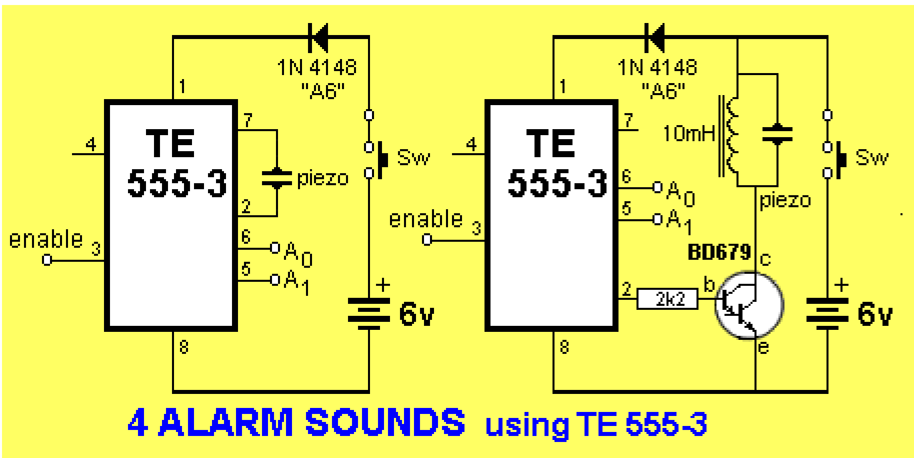


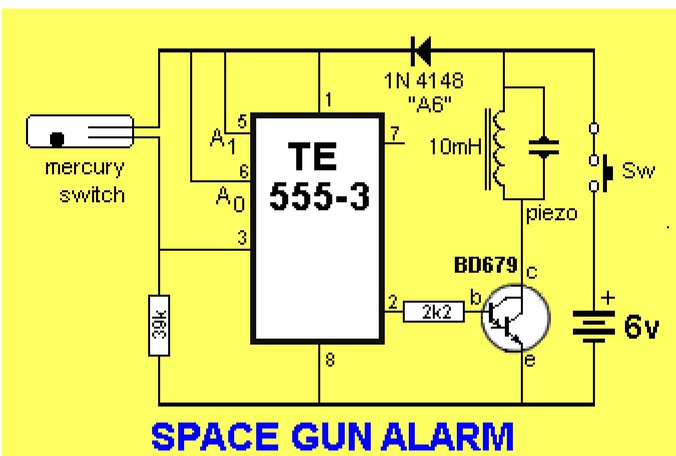
The project has two 10-LED displays. One on the front and one on the back



FOUR ALARMS SOUNDS TE555-3

This circuit uses the latest TE555-3 **FOUR ALARM SOUNDS** chip from Talking Electronics. This 8-pin chip is available for $2.50 and produces 4 different alarm sounds. The chip can be used as a complete alarm system. All you need is a piezo diaphragm and the output will be enough for a single room. To create a very loud output you can add a buffer transistor and piezo speaker and the sounds will be deafening.
Just think of it. A complete alarm circuit for $2.50 plus a switch, battery and output piezo (such as a piezo tweeter). All the components are available from Talking Electronics and you just need to email Colin Mitchell: talking@tpg.com.au with your list of items.
The output is set to produce an alarm for 3 minutes then stops.





The chip set-up as an alarm

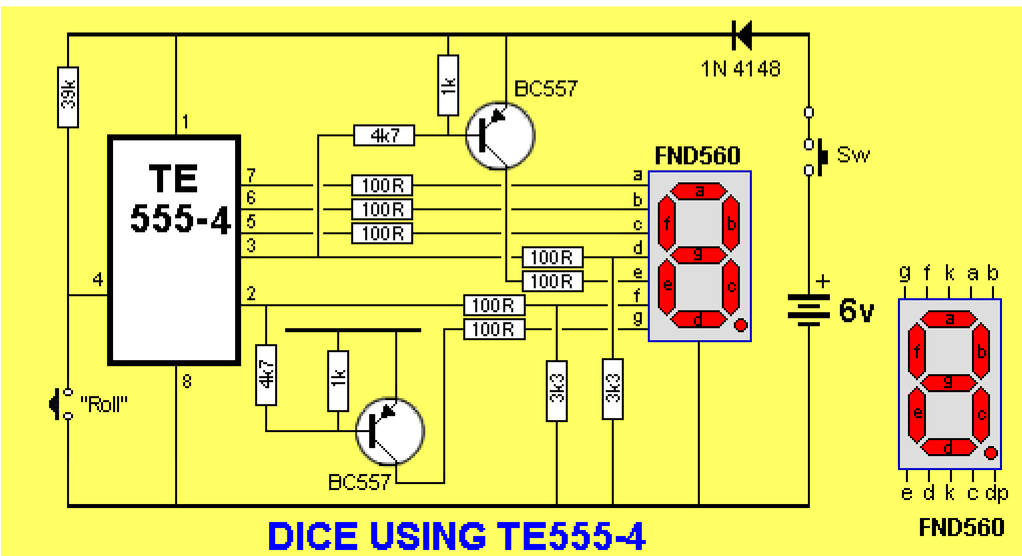
A1	A0	Alarm Output
0	0	Continuous 2.4kHz tone
0	1	Chirps
1	0	Siren
1	1	Space Gun

Control lines A0 and A1 are tied HIGH or LOW and when "enable" line is taken HIGH, the tone is emitted from pins 2 and 7 (in toggle mode). Pin 2 is LOW when the chip is at rest. To get a very loud output, pin 2 drives a Darlington transistor and

piezo tweeter with a 10mH choke across the piezo to produce a waveform of nearly 100v. The circuit consumes 0.1mA when at rest.

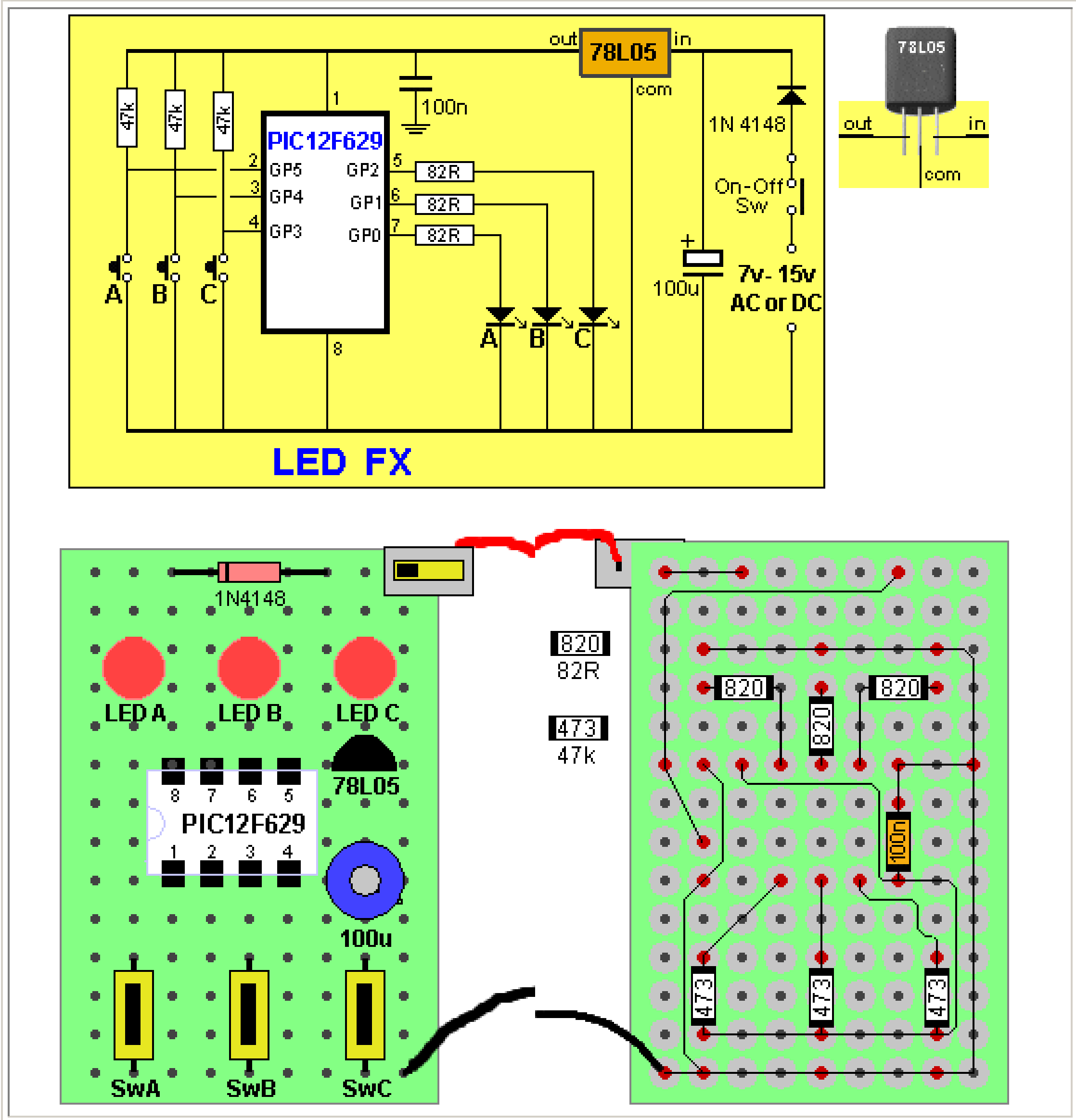
DICE TE555-4

This circuit uses the latest **TE555-4** **DICE** chip from Talking Electronics. This 8-pin chip is available for $2.50 and drives a 7-Segment display. The circuit can be assembled on proto-type board. For more help on the list of components, email Colin Mitchell: talking@tpg.com.au



LED FX TE555-5

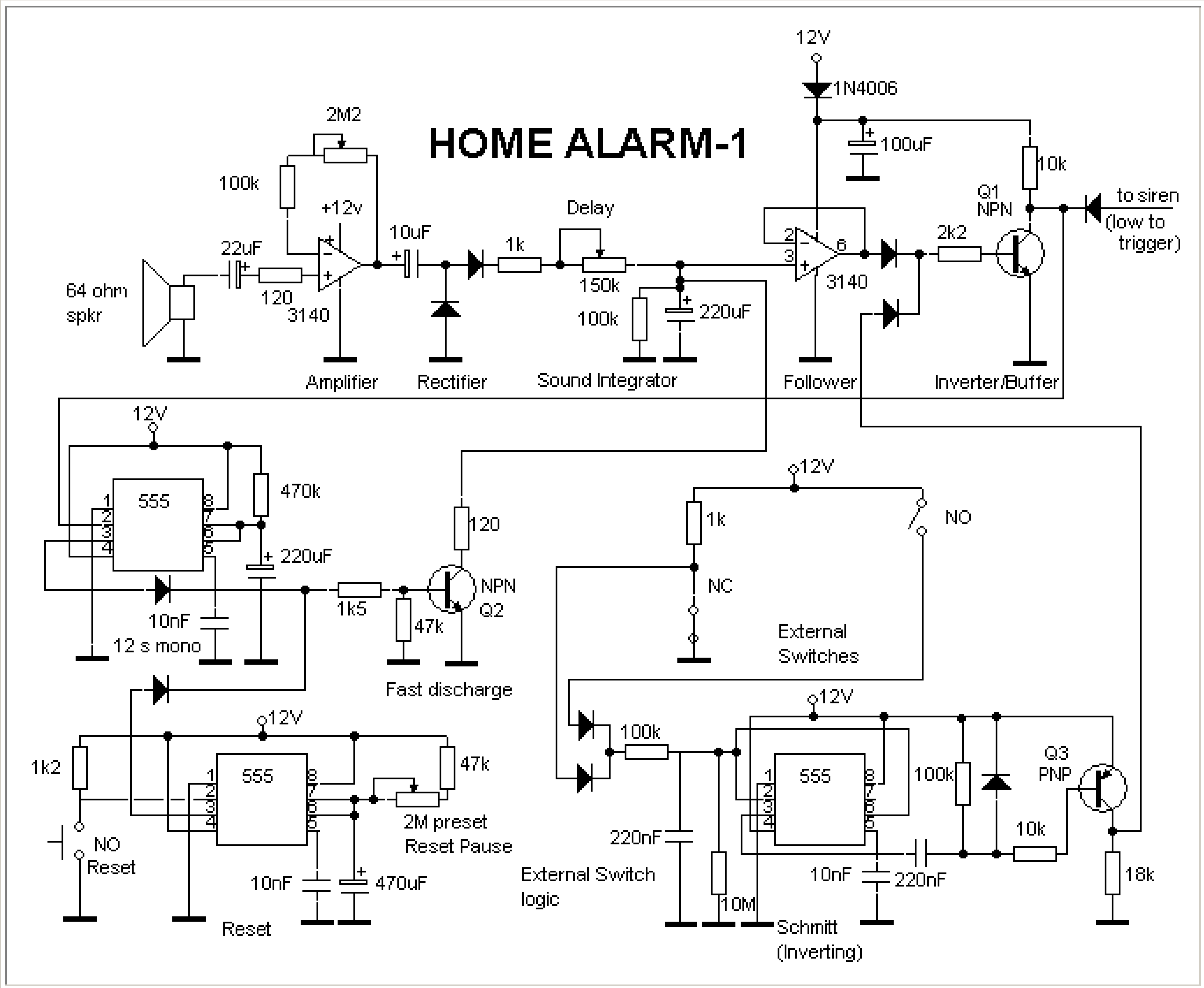
This circuit uses the latest **TE555-5** **LED FX** chip from Talking Electronics. This 8-pin chip is available for $2.50 and drives 3 LEDs. The circuit can be assembled on matrix board. The circuit produces 12 different sequences including flashing, chasing, police lights and flicker.
It also has a feature where you can create your own sequence and it will show each time the chip is turned on. The kit of components and matrix board can be purchased for $15.00 plus postage. Email Colin Mitchell: talking@tpg.com.au for more details.



78L05
out
in
com
47k
47k
47k
PIC12F629
GP5
GP4
GP3
GP2
GP1
GP0
1
2
3
4
5
6
7
8
100n
82R
82R
82R
1N 4148
On-Off
Sw
100u
7v- 15v
AC or DC
A
B
C
A
B
C
LED FX
1N4148
LED A
LED B
LED C
78L05
PIC12F629
100u
SwA
SwB
SwC
820
82R
473
47k
820
820
820
100n
473
473
473

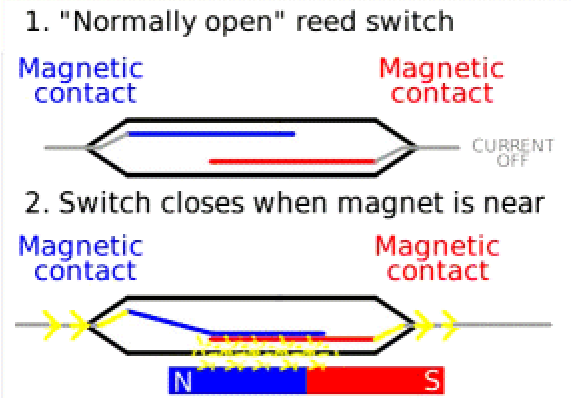
HOME ALARM-1

Here is a Home Alarm using 555 IC's.



BURGLAR ALARM 4-ZONE

This circuit uses a dedicated alarm chip from Talking Electronics (**TE555-BA4**). The chip costs $2.50 and contains a 4-zone Burglar Alarm circuit. All you need are the surrounding components to complete the project. These components are available as a kit for $20.00 including the dedicated chip and this makes it one of the cheapest kits on the market (postage for kit $6.50). Click HERE to order the chip or the kit.
The only additional parts you require are 4 reed switches. These can be purchased on eBay for $5.38 for a set of 5 Normally Open switches (post free).
Here is the link:
http://www.ebay.com/itm/5-Set-Door-Or-Window-Safety-Contact-Magnetic-Alarm-Reed-Switch-NO-with-Screws-/290746194636?pt=LH_DefaultDomain_0&hash=item43b1d2dacc

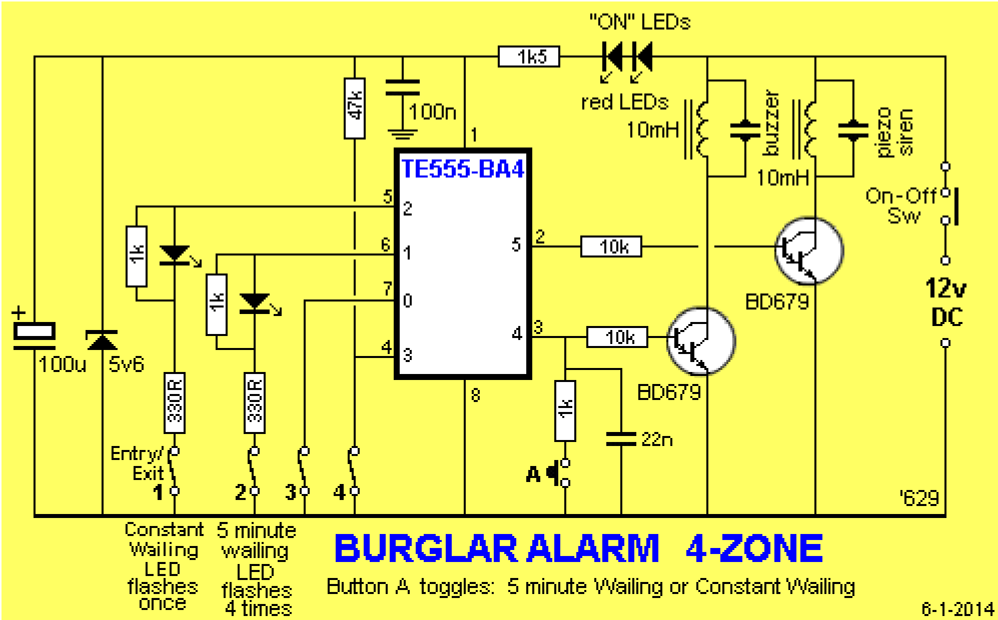


Build the circuit on a piece of matrix board (or the Circuit Board included in the kit) and connect the inputs to the screw terminals. 6 separate 2-screw terminals are provided in the kit to make it easy to wire-up the alarm. The alarm takes about 1mA when monitoring a house and about 100mA when activated.

The siren is only activated ONCE for 5 minutes when a break-in occurs as this is the maximum allowable time for a siren to wail in Australia.

If you want the alarm to constantly wail after a break-in, push button A when the alarm is turned on (and the exit beep is being produced). The constantly wailing LED will flash. Push the button again and the 5 minute LED will flash. The button toggles between the two features.

You can use reed switches for the input devices for doors and drawers. You can also trap the burglar by placing money under a clip and have a very thin length of tinned copper wire wound around two pins. When the money is removed, the wire is pulled off the pins. A single strand of wire can be obtained from a length of hook-up flex.



POWER SUPPLY

The alarm can be connected to a 12v gell cell with a rating of 1.2AHr and it can be automatically charged using our

Automatic Battery Charger in 101 Transistor Circuits.

http://www.talkingelectronics.com/projects/200TrCcts/101-200TrCcts.html#84

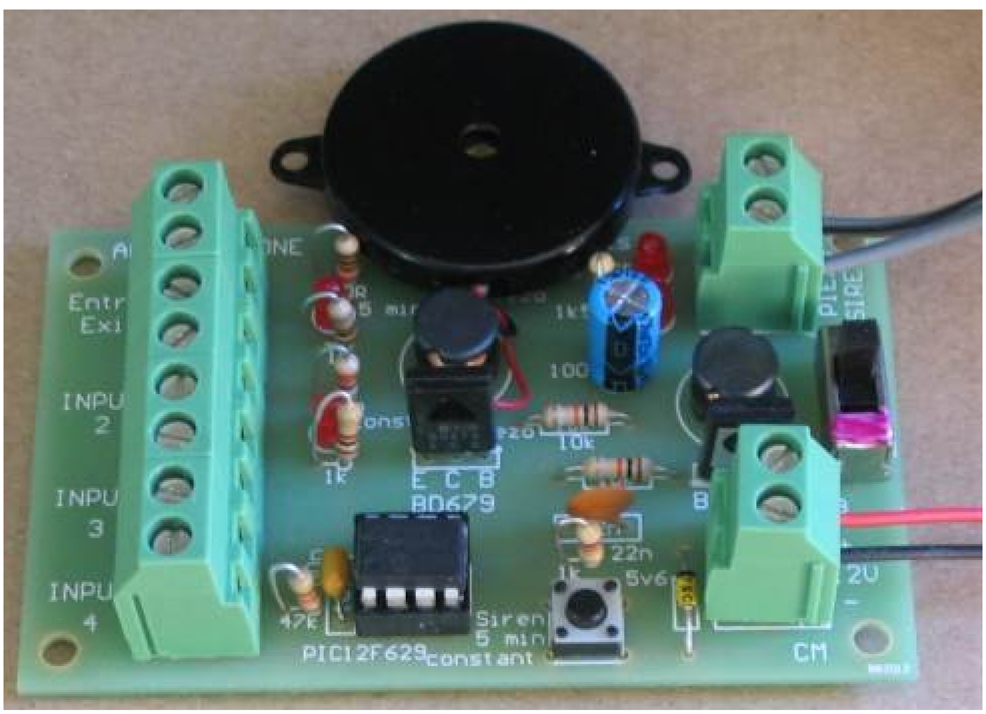
HOW THE CIRCUIT WORKS

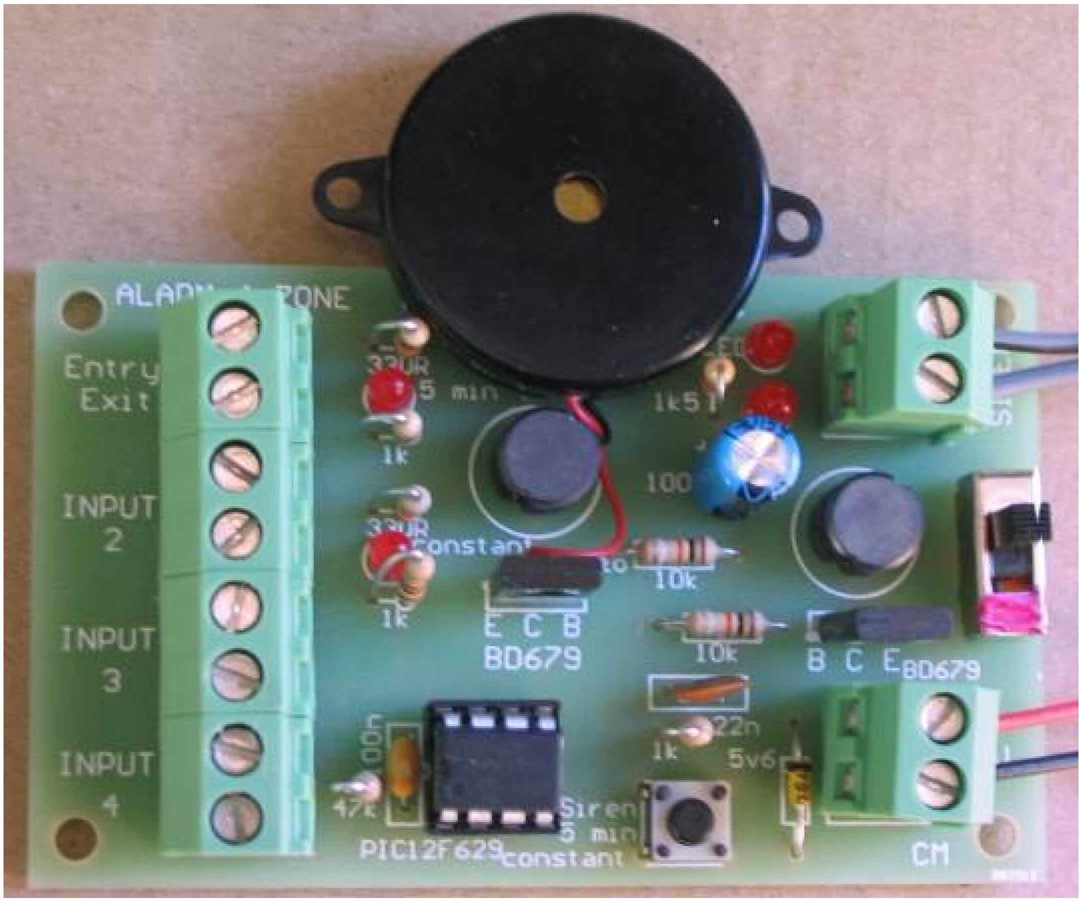
Any of the inputs can be used for the Entry/Exit.

It is connected to the door you will use to enter or exit the property. The alarm gives you 45 seconds to exit.

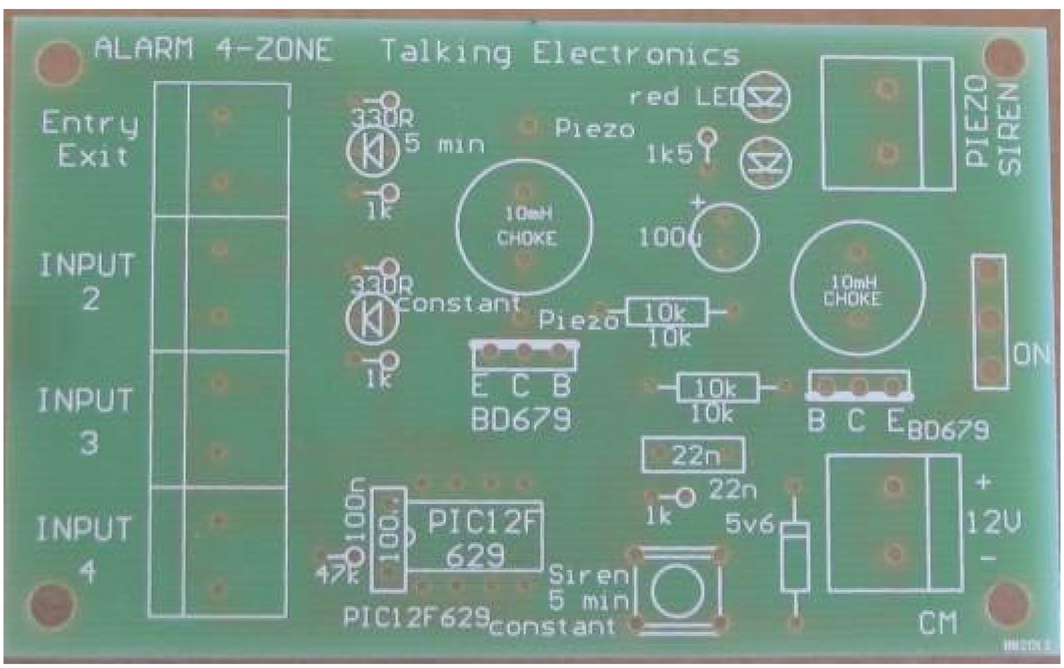
When you enter the property, the buzzer turns on as soon as you open the door and beeps for 45 seconds to allow you to turn off the alarm.

If the alarm is not turned off, the main piezo siren produces a soft tone for 30 seconds and then a piercing wailing sound.





This allows you to turn off the alarm before the loud wailing is produced and is one of the best features of the alarm as the worry of false-triggering an alarm prevents many householders setting their alarm.
Any unused inputs must be connected with a link so the alarm can be set.
When the circuit is turned ON, you have 45 seconds to exit the premises.
The chip then flashes either the 5-min LED or the Constant LED to indicate if the siren will wail for 5 minutes or constantly. You can change the setting by pressing the button. The circuit then beeps for 45 seconds to give you time to exit the property. It then monitors all 4 inputs.



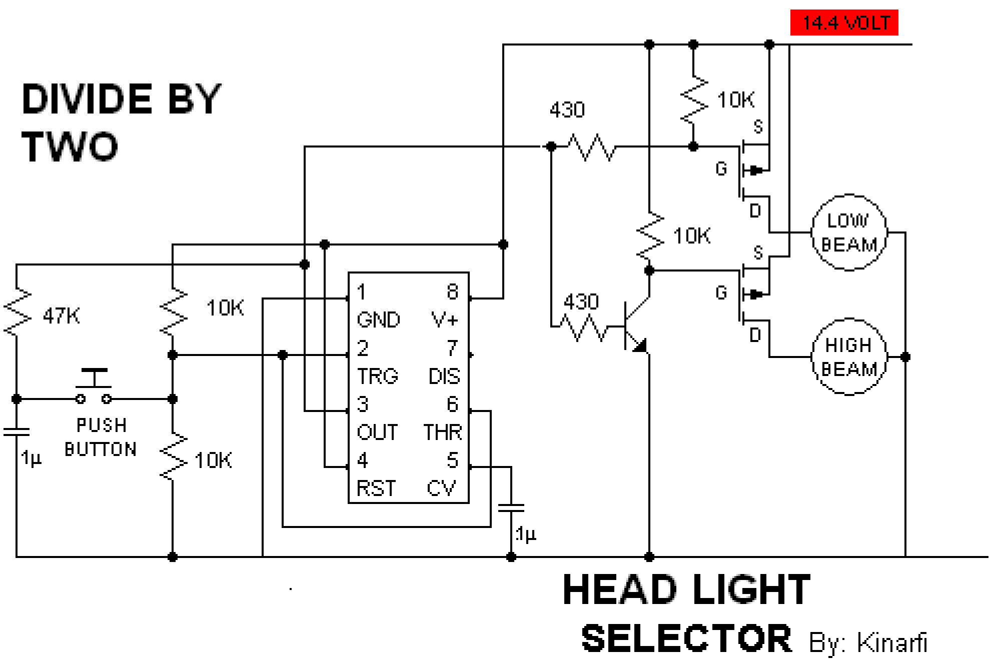
Alarm 4-Zone PCB

The main chip contains an internal oscillator to drive a piezo diaphragm and also a wailing

oscillator for the Piezo Siren. The Piezo Siren is an 80dB piezo diaphragm driven by a BD679 Darlington transistor with a 10mH choke to produce a high voltage for the diaphragm.
The chip operates on 5v and the rest of the circuit uses 12v. A very simple voltage-dropper consisting of 2 LEDs and 1k5 drops the 12v to 5v.

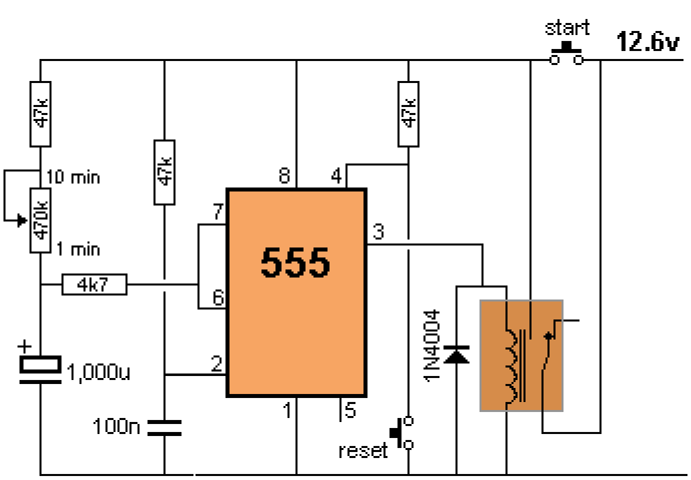
HEADLIGHT SELECTOR

This circuit was designed by a reader who needed to select between low and high beam by pressing a switch, then change back by pressing the switch again. The circuit always starts on low beam, regardless of the state when it was turned off.



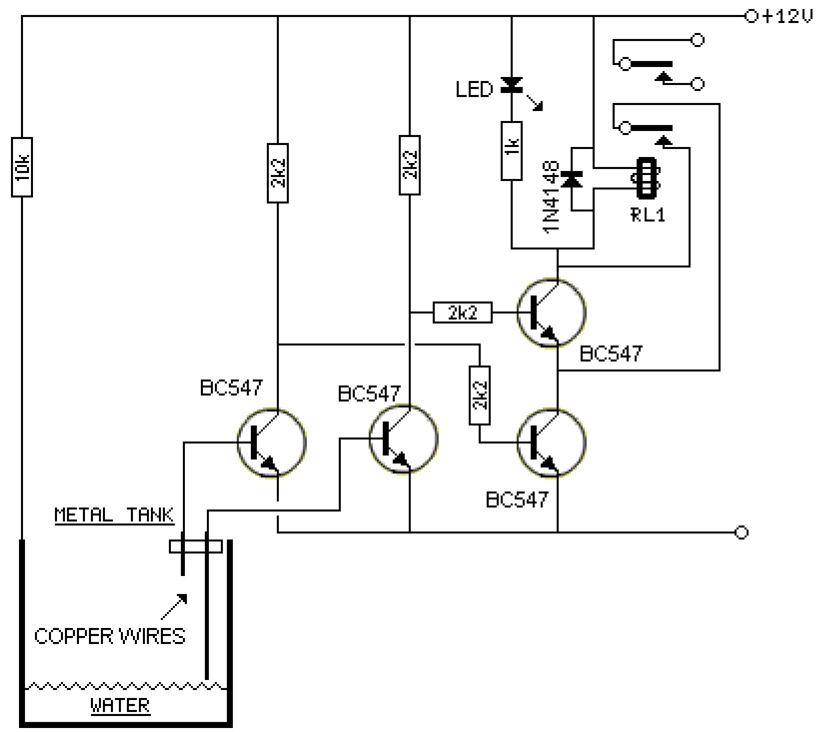
1-10 MINUTE AUTO TURN OFF

This circuit provides an automatic turn-off feature after a time that can be set from 1 minute to 10 minutes by the 470k pot.

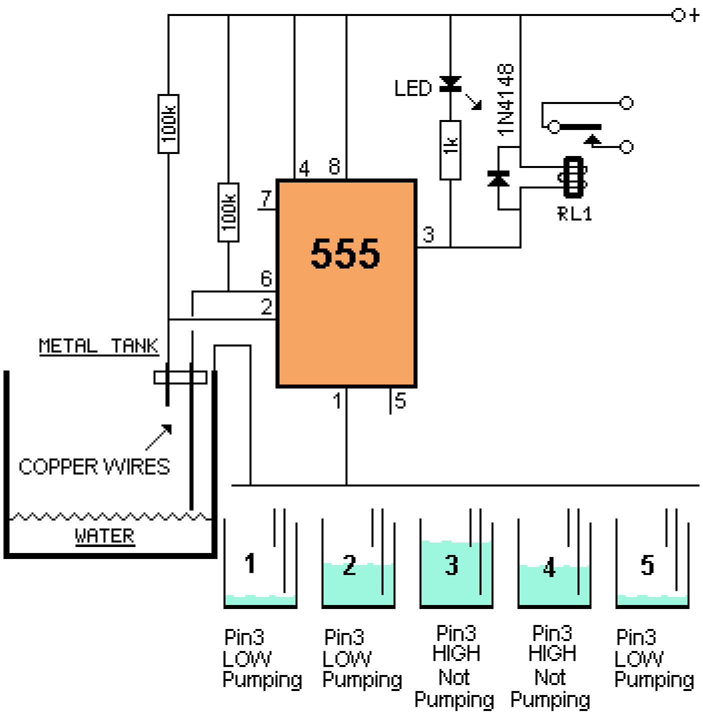


WATER LEVEL DETECTOR

This circuit can be used to automatically keep the header tank filled. It uses a double-pole relay. This is the transistor version of the circuit below.



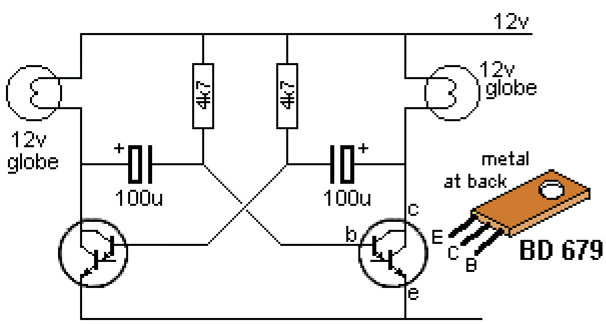
Here is the circuit using a 555:
These are the facts you have to remember. In our circuit, Pins 2 and 6 detect a voltage when water is not touching the probes, due to the 100k resistors. When water touches the probes, neither pin "detects a voltage."
Don't worry about pin 2 detecting 1/3 of rail voltage and pin 6 detecting 2/3 of rail voltage. In our circuit the pins either detect a voltage or do not detect a voltage. Pin 2 detects a LOW and pin 6 detects a HIGH. Pin 2 does nothing when it detects a HIGH and pin 6 does nothing when it detects a LOW.
When the water is LOW, as shown in **fig 1**, both pins 2 and 6 are HIGH and the output of the 555 is LOW.
As the water rises, as shown in **fig 2**, Pin 6 goes low but nothing happens to pin 3 except the chip "has been prepared via the internal flip-flop" to change when pin 2 goes LOW. When the water reaches pin 2, as shown in **fig 3**, this pin "fails to see a HIGH," the output of the chip goes HIGH and the pump turns off.
As the water level goes down, as shown in **fig 4**, pin 2 sees a HIGH but this does not change the 555 as pin 2 only has an effect when it goes LOW.
When the water level goes down further, as shown in **fig 5**, pin 6 sees a HIGH and because pin 2 is not seeing a LOW, the chip will change states. The output goes LOW.



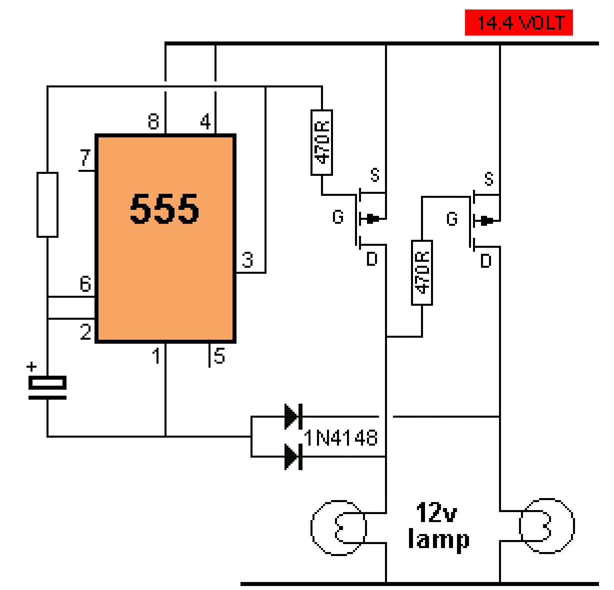
Here's the circuit used in a hydroponic garden, to grow tomatoes:
http://indoorhydroponicveggies.wordpress.com/#waterleveldetector

WARNING LIGHTS FLASHER

These two circuits flash two **5 watt to 21watt** car lamps. The first circuit uses BD679 Darlington transistors and the second circuit uses a 555.



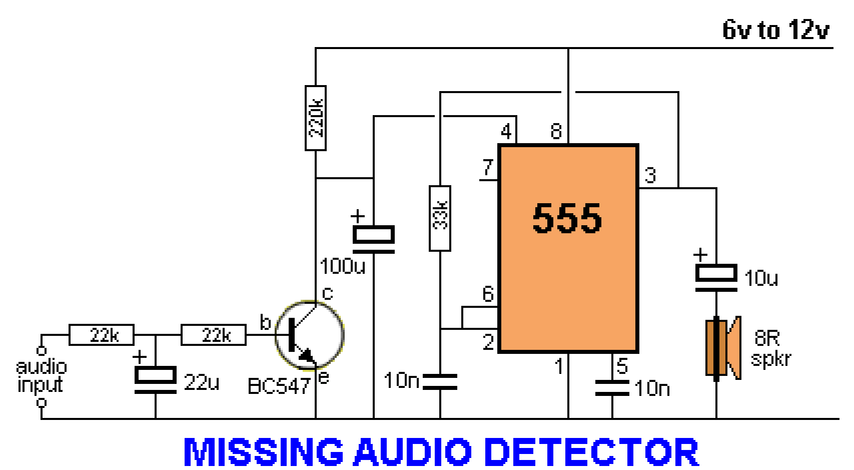
This 12v Warning Beacon is suitable for a car or truck break-down on the side of the road. The key to the operation of the circuit is the high gain of the Darlington transistors. The circuit must be kept "tight" (thick wires) to be sure it will oscillate.
A complete kits of parts and PC board costs $5.00 plus postage from: Talking Electronics. Email HERE for details.



The 555 circuit uses two diodes to connect the chip to the negative rail and this allows the components to be fitted between the "high side" of the lamps and the "power switch."

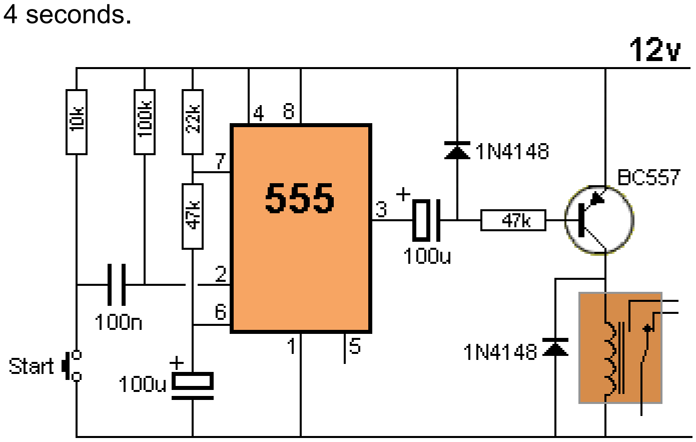
MISSING AUDIO DETECTOR

This circuit detects when audio is not received for about 4 seconds and turns on an alarm.



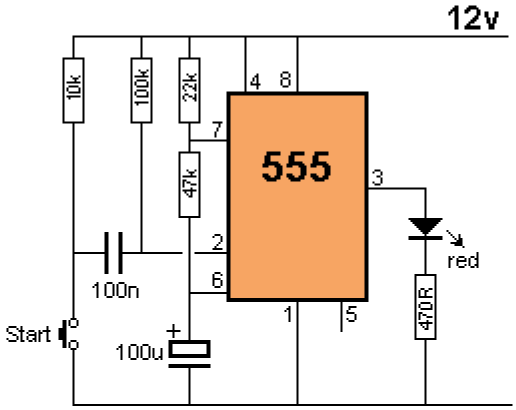
5 SECS DELAY THEN RELAY ON FOR 4 SECONDS

This circuit waits 5 seconds before turning on the relay for 4 seconds.



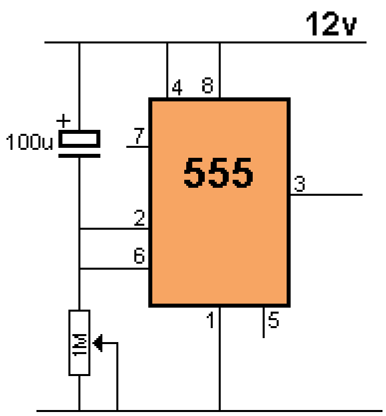
5 SEC ON - even if switch is kept pressed

This circuit illuminates a LED for 5 seconds - even if the switch is kept pressed.



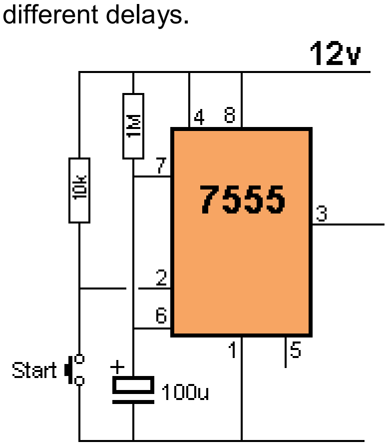
DELAY BEFORE TURNING ON

This circuit does not turn on for XX seconds after power is applied. Adjustable from 1 second to 2 minutes.



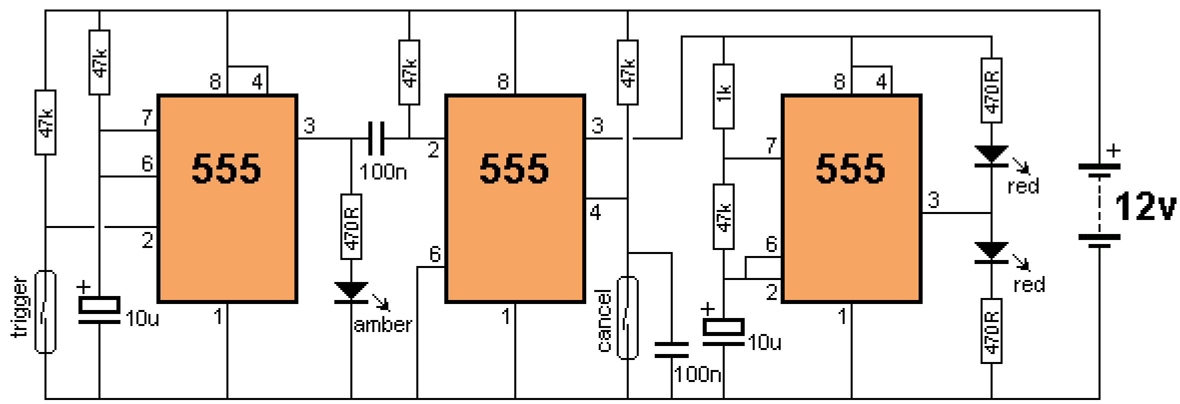
LOW CURRENT TIMER (delay)

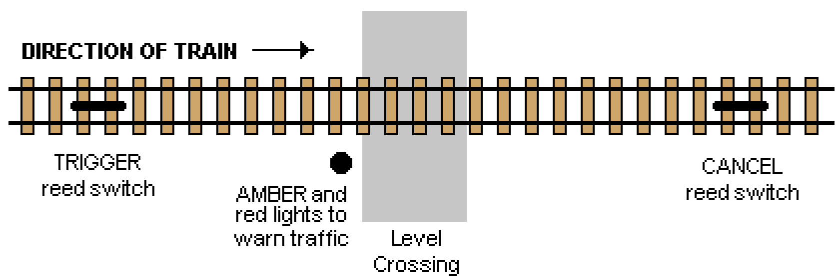
The low-current version of the 555 is called 7555 (ICM7555CN), and is a CMOS direct-equivalent version of the TTL 555. It costs more but can be purchased on eBay for $12 (for 10 items incl postage). The normal standing current for a 555 is about 10mA. The standing current for a 7555 is about 0.3mA. This circuit will produce a delay of about 5mins. Change the 1M and/or 100u for different delays.



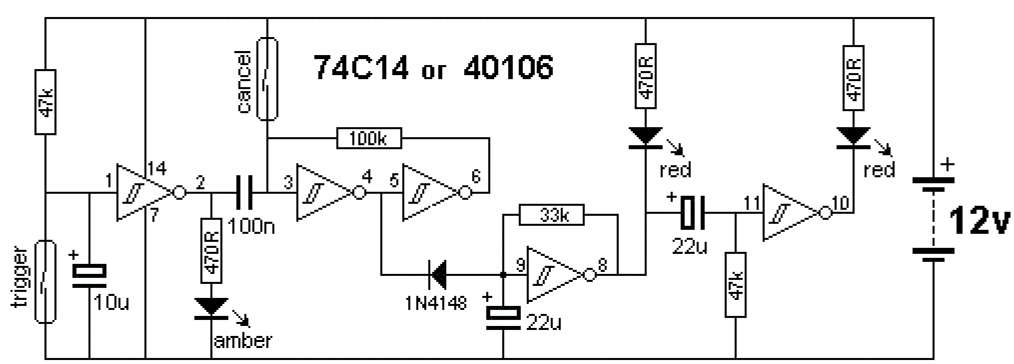
CROSSING LIGHTS

A magnet on the train activates the TRIGGER reed switch to turn on the amber LED for a time determined by the value of the first 10u and 47k.
When the first 555 IC turns off, the 100n is uncharged because both ends are at rail voltage and it pulses pin 2 of the middle 555 LOW. This activates the 555 and pin 3 goes HIGH. This pin supplies rail voltage to the third 555 and the two red LEDs are alternately flashed. When the train passes the CANCEL reed switch, pin 4 of the middle 555 is taken LOW and the red LEDs stop flashing.
See it in action: Movie (4MB)



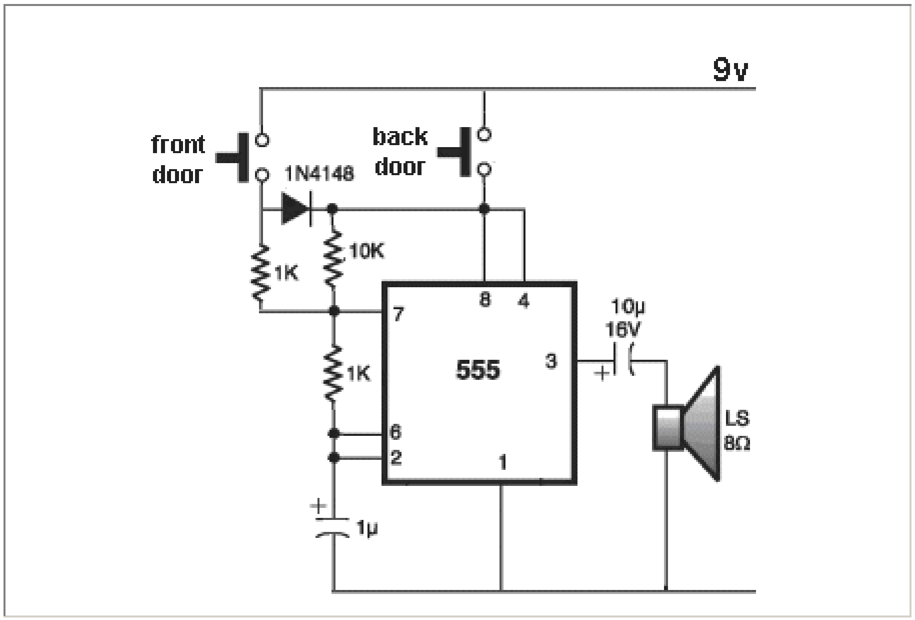


The circuit can also be constructed with a 40106 HEX Schmitt trigger IC (74C14). The 555 circuit consumes about 30mA when sitting and waiting. The 40106 circuit consumes less than 1mA.



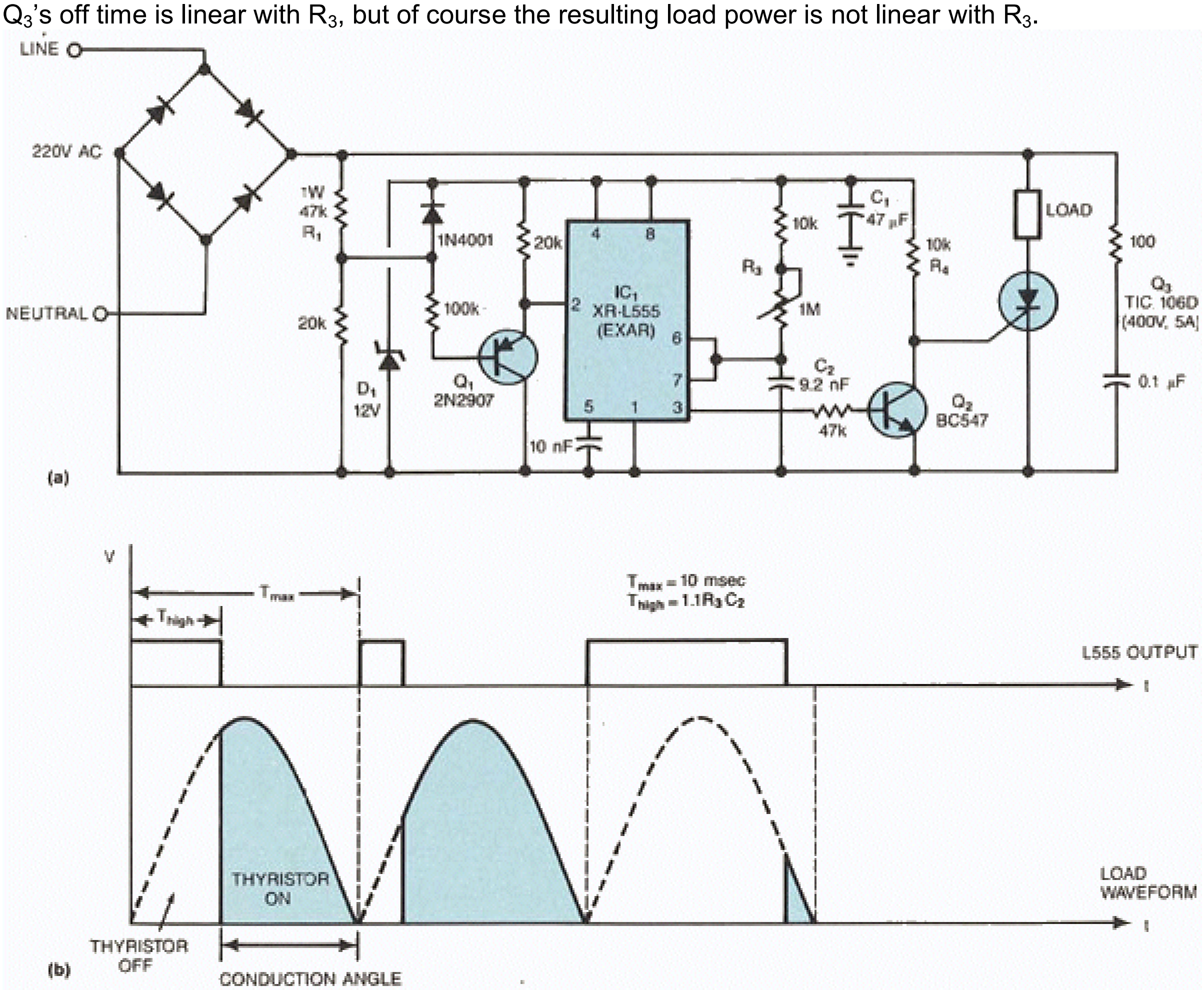
DOORBELL for FRONT DOOR and BACK DOOR

This circuit produces two different sounds. One for the front door and one for the back door. The circuit takes NO CURRENT when not producing a sound and a 9v battery will last for many months.



PHASE CONTROL

The control circuit in **Figure 1a** allows you to manually adjust the power delivered to a load. By changing the setting of potentiometer R_3 you change the phase angle at which the thyristor (Q_3) fires (**Figure 1b**), thereby altering the load current's duty cycle. The adjustment range is about 0 to 180°. Q_3's off time is linear with R_3, but of course the resulting load power is not linear with R_3.



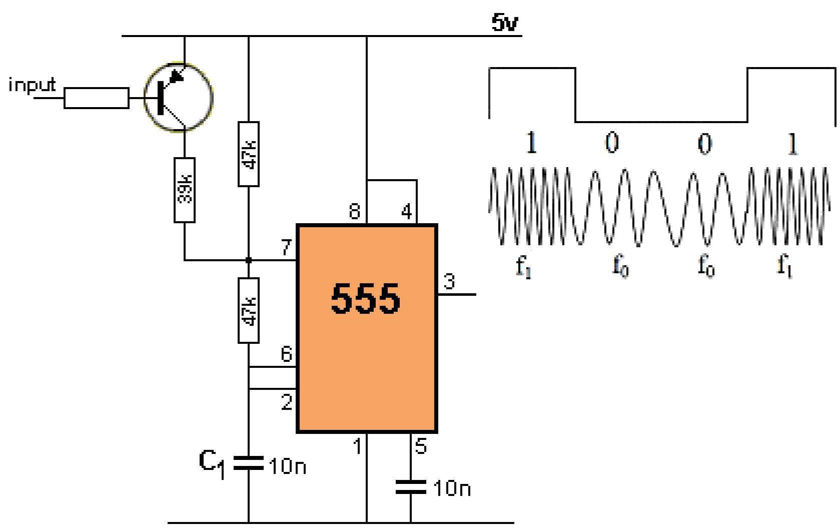
The full-wave diode bridge delivers pulsed-dc voltage to the load, making the circuit suitable for dc-control applications such as dimming. (The circuit can handle ac power if you substitute a triac for Q_3 and make slight modifications.)

IC_1 is a low-power—1 mW—timer configured as a monostable. Zener diode D_1 and filter capacitor C_1, activated by pulses from the voltage divider R_1/R_2, form a dc supply for the timer. Q_1 turns on and applies a negative-going trigger to the timer (pin 2) each time Q_1's base voltage approaches 0V. In

response, the timer issues a positive pulse that turns on Q_2 and turns off Q_1, removing load power for an interval equal to $1.1R_3C_2$. To increase the control resolution, you can lower the value of R_3, substitute a potentiometer with more turns, or add a fixed resistor in series with the potentiometer.

FREQUENCY SHIFT KEYING (FSK)

A digital signal can be converted to an analogue signal for transmission through the phone line. The signal consists of two different frequencies. One standard is 1270 for logic 1 (Mark) and 1070 for logic 0 (Space). The circuit below shows how to use a 555 to produce two different frequencies.



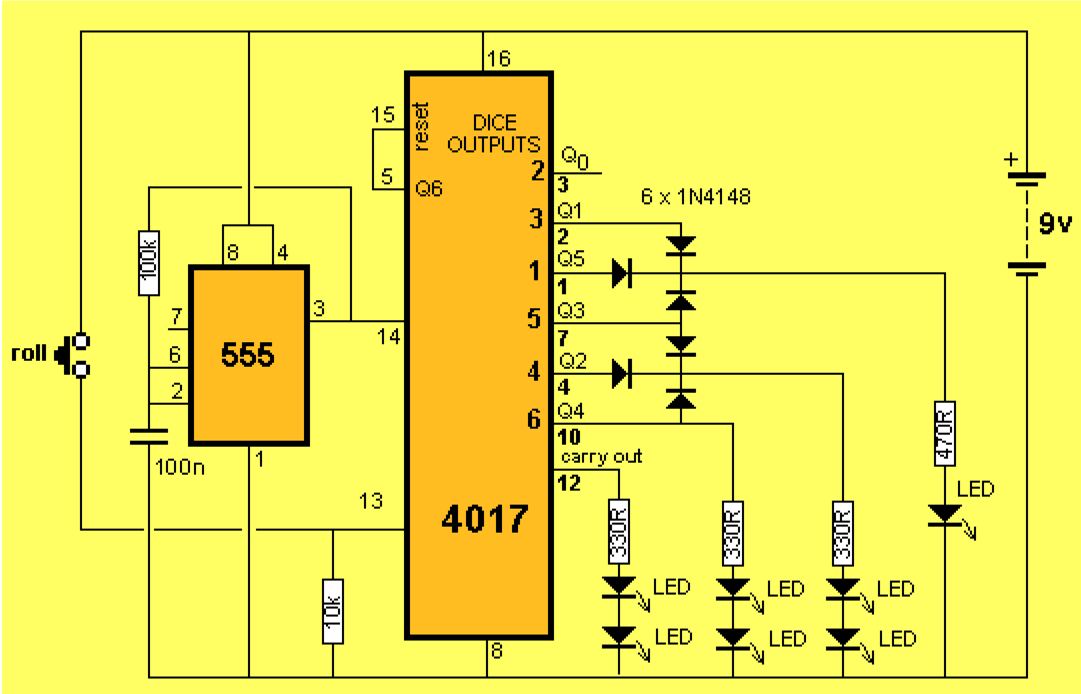
FREQUENCY SHIFT KEYING (FSK)

LED DICE

A SIMPLER CIRCUIT:

The circuit above can be simplified and output Pin 12 can be used to illuminate two of the LEDs as this line is HIGH for the times when Q0, Q1, Q2, Q3, and Q4 are HIGH and goes LOW when Q5 - Q9 is HIGH.

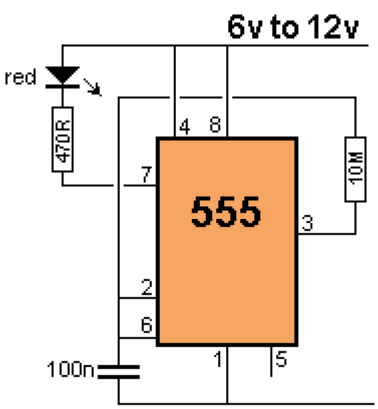
This means the 4017 starts with Q0 HIGH. But Q0 is not an output. This means that when Q0 is HIGH, "carry out" is HIGH and "2" will be displayed. The next clock cycle will produce "3" on the display when Q1 is HIGH, then "4" when Q2 is HIGH, "5" when Q3 is HIGH and "6" when Q4 is HIGH. When Q5 goes HIGH, it illuminates "1" on the display because "carry out" goes LOW.



LED DICE - minimum components

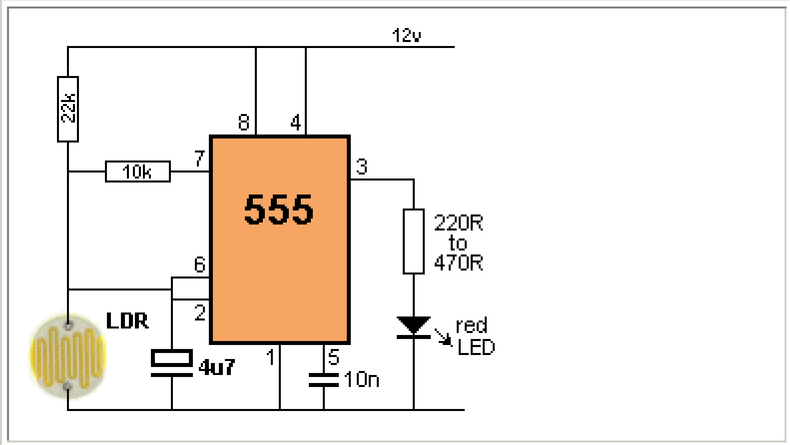
LED FLASHER

This circuit uses Pin 7 to turn on the LED and the capacitor is non-electrolytic to keep the circuit small.
Designed by Franz Bachler, this arrangement has never been presented before:



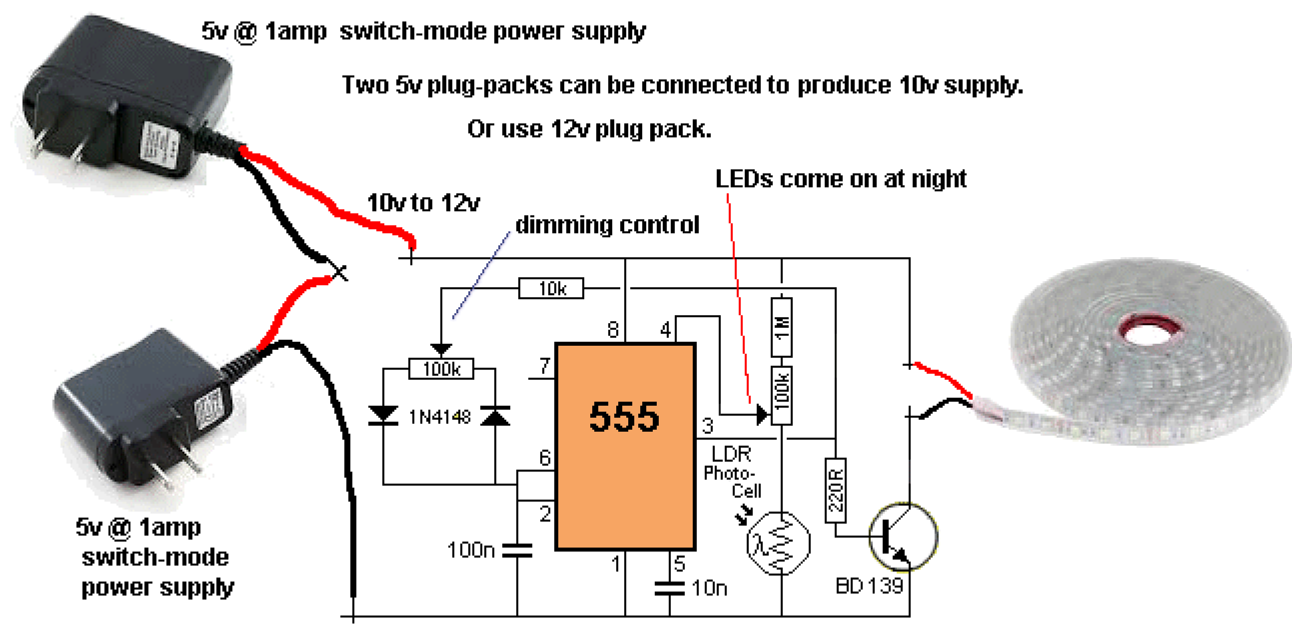
LED FLASHER with LDR

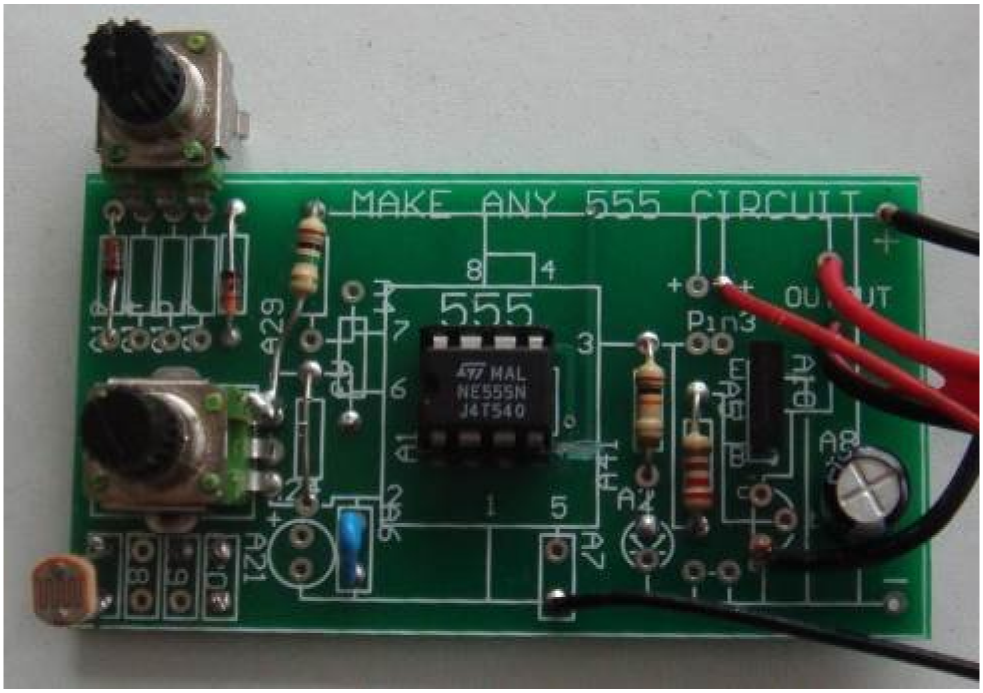
This circuit uses the fact that pin 6 needs to reach 2/3 rail voltage for the 555 to cycle. When light falls on the LDR, it produces a voltage-divider with the 22k to prevent pin 6 seeing 66% rail voltage and the LED stops flashing.



Automatic Garden LED Strip

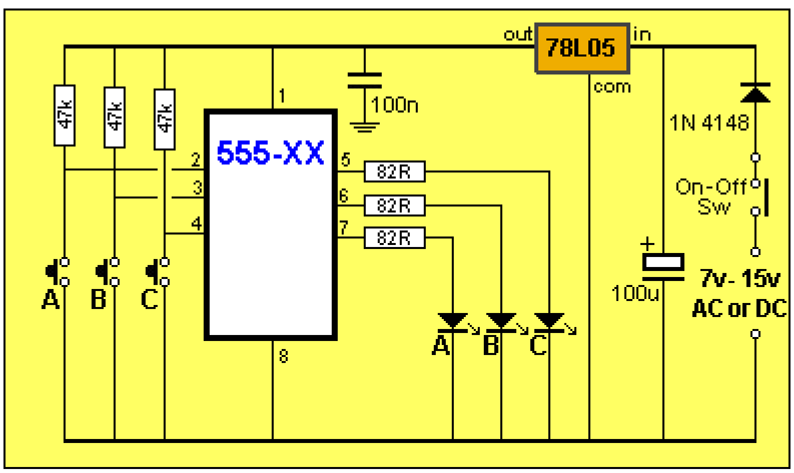
This circuit uses two 5v switch-mode power supplies to create a 10v power supply.
You can do this with almost any two wall worts (plug packs) to get any desired voltage.
The circuit only turns on at night and the brightness of the LEDs can be controlled by the "dimming Control."
This project uses one of our "Make any 555 Project" PC boards. The two 5v @1 amp SMPS modules were connected to TWO 5 metre LED strips and the brightness turned down considerably as the whole driveway was illuminated and kept the neighbours up all night !!!! The estimated wattage was less than 5 watts for the 600 LEDs. The electricity cost is less than $5.00 per year to illuminate a dark driveway and make it safe for you and your visitors. Here is the .pdf of this project.

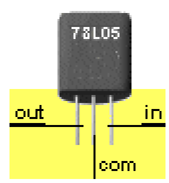




The **Make Any 555 Project** PC board allows you to create a beautiful project very easily and quickly.
90% of the circuit is already provided and all you have to do is cut a few tracks and add a few wires under the board and the project is complete.

The Universal 555



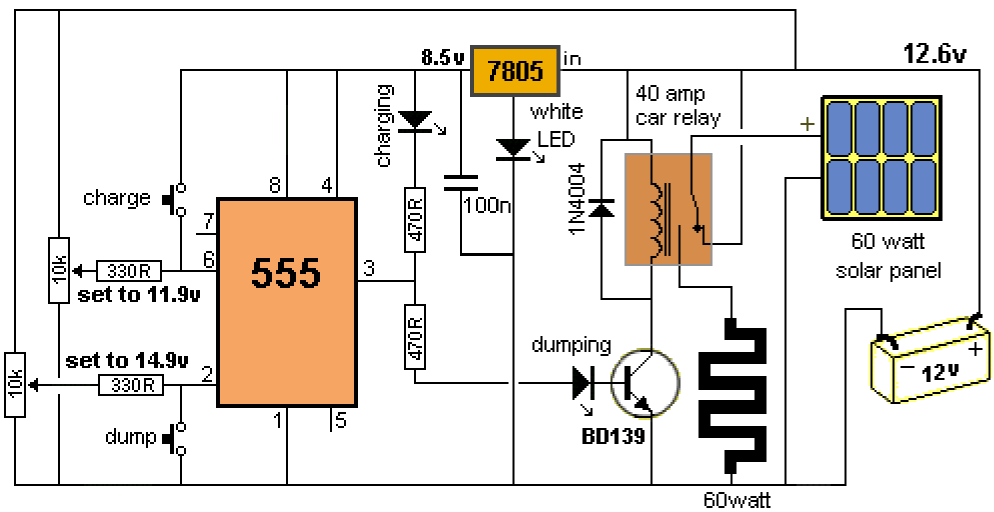


We have shown how hundreds of circuits can be made with the 555 but some requirements are too complex for this amazing chip.
Something as simple as:
I want to make a circuit that detects sensor 1 and within 1 sec it needs to detect sensor 2. If it does there is no problem but when detection of sensor 2 is more than 1 second I need to shut down the machine. It's for a project and I don't know which circuit I can use with the 555 timer.
This simple requirement will take a lot of circuitry using 555 chips and it is more complex than you think.
That's why they invented microcontrollers.
They simplify the requirement to a single chip and a few components.
The circuit above turns on LED A when SwA is pressed. But if SwB is pressed within 1 second, the LED is turned OFF.
The output needs to go HIGH when SwA is pressed and a 1 second timer allows Sw B to turn OFF the output within 1 second.
This is a timer (or delay) plus gating requirement as well as a "latch" requirement the switches are only momentary pulses.
Personally I would not waste time with individual chips (gates) as at least 4 building blocks are needed. A program only requires 10 lines of code plus a sub-routine.
Simply look at SwA to turn ON the output and call a 100mS delay routine (10

times) while looking at SwB to turn OFF the output.
This is covered in **PIC Fx-1** project and you can contact Colin Mitchell for more details.

CHARGE CONTROLLER

This circuit prevents a battery being overcharged. When the battery is FULLY CHARGED, the energy from the solar panel is dumped into a LOAD. This load can be a 12v 100watt globe or a high-power resistor.
You only have to dump excess current if your solar panel is capable of fully charging the battery in less than 10 hours.
If it takes 14 or more hours of sunlight to charge the battery, this is equal to 2 days of illumination and the battery will accept this low rate of charge and you possibly don't need this circuit.
A simple way of charging a battery without needing this circuit is to put a high wattage resistor and diode in series with the positive line of the solar panel and the battery.
The solar panel will then simply trickle charge the battery over a few days.



SETTING UP

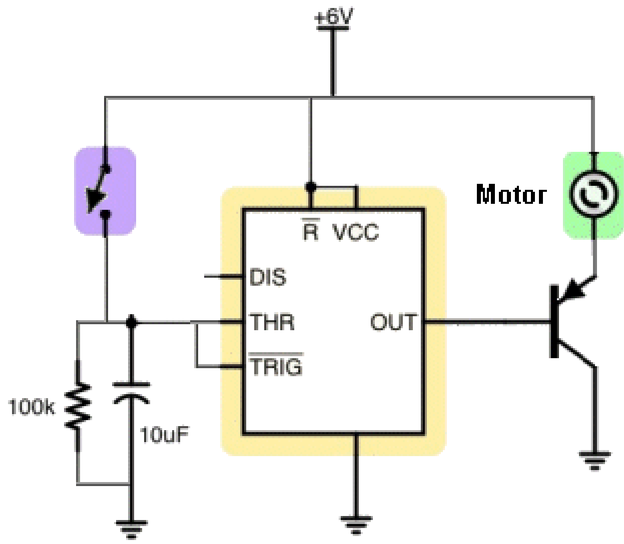
Use a variable power supply.
You don't need the high wattage resistor or the battery or solar panel or the relay!.
Connect the variable power supply set to 11.9v. Adjust the top 10k pot to turn ON the charging LED.
Increase the voltage to 14.9v and adjust the lower 10k pot to make the dumping LED come on.
Now connect all the components as shown in the circuit and check the voltage levels once more before installing the project.
The white LED "jacks up" the 7805 to produce 8.5v output as the 555 does not like a voltage as low as 5v.
To manually "charge" or "dump" energy, simply press either button quickly and the 555 will toggle to the required state and perform the operation of charging or discharging.

If you don't have a variable power supply, here's what you do:
Get a small 12v battery and fit it to the circuit.
It will charge very quickly and you will be able to keep reading the voltage across the battery as it charges. Adjust the HIGH and LOW voltages (called "set points") as close as possible and watch the circuit cycle "up and down."
Each time you see it "cycle" you can fine-tune the exact voltages until you see it change at 11.9v and 14.9v.
In fact you can use **any** set of old "junk" rechargeable cells to perform this test as you are simply reading a high and low voltage and waiting for it to reach these values over a short period of time.

MOTOR OVER-RUN

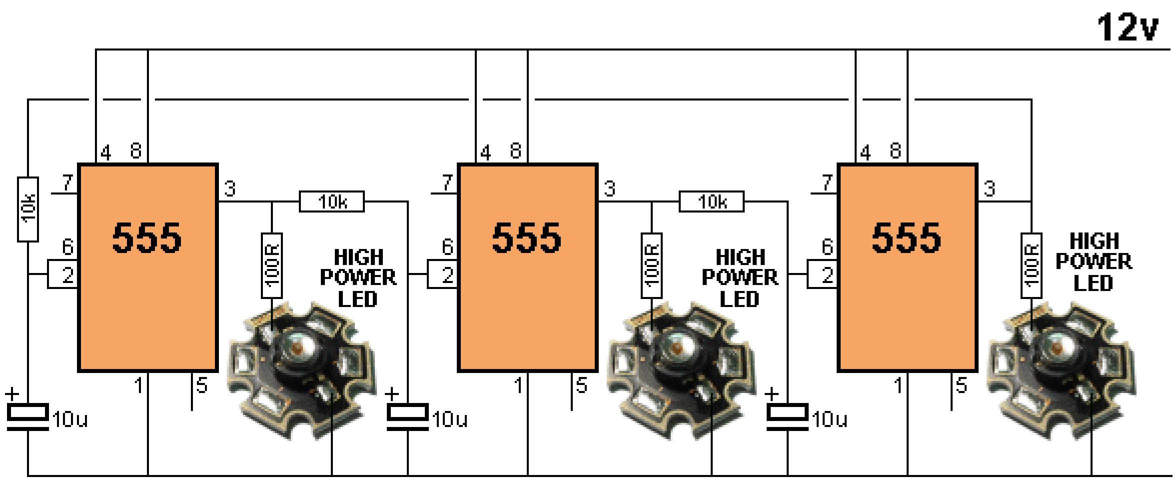
The motor continues to operate about 2 seconds after the switch

is opened, until the 10u drops below 33% of rail voltage, as is discharged via the 100k.



3-CHASE CHASER

555 chips are not very expensive and you can use them like "lollies" to create all sorts of effects.
This circuit produces a "chase effect" with 2 LEDs ON at any one time.
The advantage of this circuit is the HIGH POWER LEDs that can be connected to the output of the chips.
You cannot add any more stages as the circuit will not be self-starting.



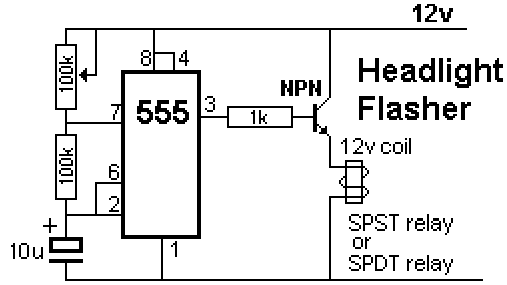
FAULTS

Here are some circuits with faults. They come from projects on the web:

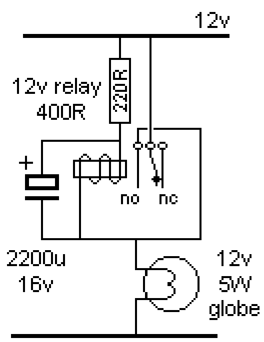
HEADLIGHT FLASHER

This circuit flashes headlights via a relay but the relay is only getting 9v4 due to the voltage-loss of the 555 and 0.6v of the transistor: The transistor should be common-emitter configuration.
In addition, the pot will be damaged if turned to zero ohms. A 1k

should be placed in series with the pot (at pin7 end).

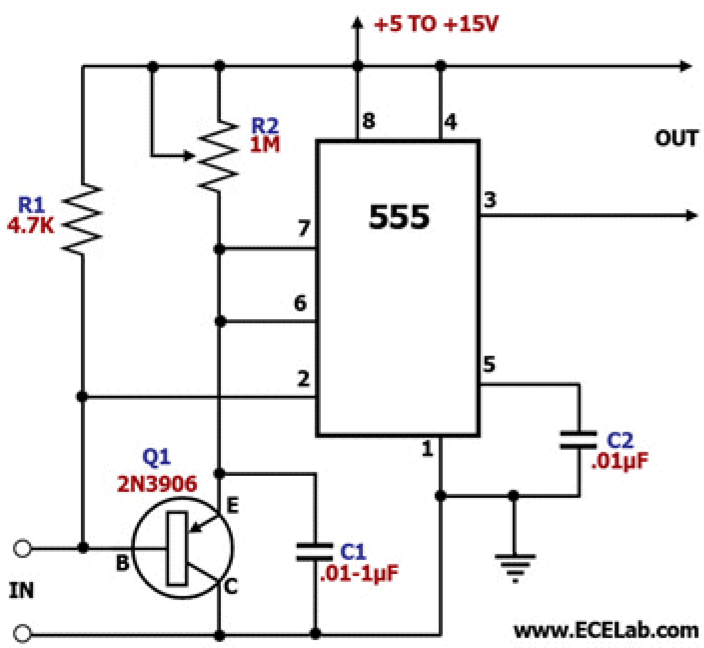


Here is a simpler circuit. It will need testing and adjusting to suit the relay you will be using:



MISSING PULSE DETECTOR

This circuit is described on the web as a missing pulse detector. If the 1M pot is turned to zero ohms, it will be damaged when the transistor inside the 555 at pin 7 connects to 0v rail.



MERCURY SWITCH DETECTOR

This circuit is a LATCH CIRCUIT and it detects when the mercury switch is tilted. But it is consuming 10mA while it is sitting around waiting for the mercury switch to make contact. By replacing the 555 with two transistors, the circuit will consume zero current when waiting for the switch to close. Sometimes a 555 is not the ideal choice.

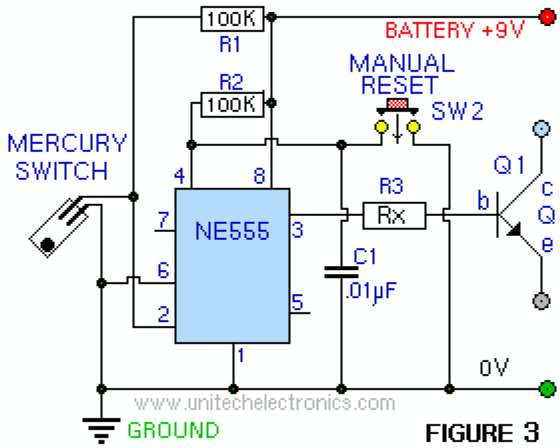
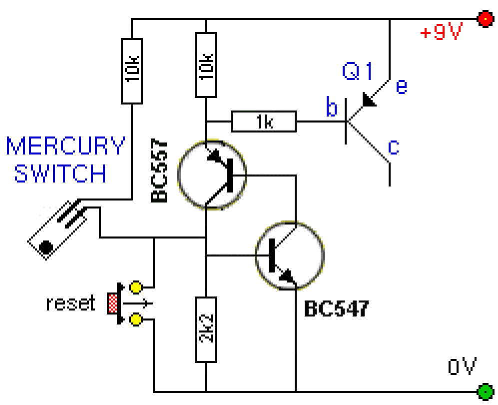
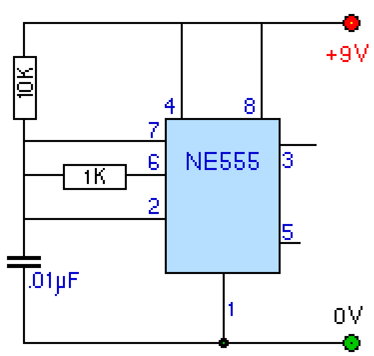


FIGURE 3
MERCURY TILT SWITCH DETECTION



MERCURY TILT SWITCH DETECTION



What is the purpose of the 1k resistor?
Pin 6 is a high-impedance pin and 1k (or any value) will have no effect.
(the same with pin 2). It is not needed.

BUY NOW

555 KIT

A kit of components to make many of the circuits described in this eBook is available for $10.00 plus $7.00 post.
Or email Colin Mitchell: talking@tpg.com.au

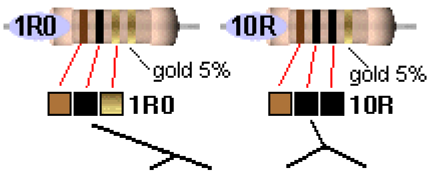
The kit contains the following components:
(plus **extra** 30 resistors and 10 capacitors for experimenting), plus:

2 - 220R
2 - 1k

2 - 4k7
2 - 10k
2 - 33k
2- 100k
2 - 1M
1 - 10k mini pot
1 - 100k mini pot
2 - 10n
2 - 100n
1 - 10u electrolytic
1- 100u electrolytic
2 - 1N4148 signal diodes
2 - BC547 transistors
1 - BC557 transistor
1 - 555 timer chip
1 - 8 pin IC socket
1 - red LED
1 - green LED
1 - orange LED
1 - mini 8R speaker
1 - mini piezo
1 - LDR (Light Dependent Resistor)
1 - 10mH inductor
1 - push button
4 - tactile push buttons
1 - **Experimenter Board** (will take 8, 14 and 16 pin chips)

THE FUTURE

**This eBook has shown the enormous number of circuits that can be produced with a 555.
However there is something we should point out.
The 555 has limitations and disadvantages.
It is not a chip you readily add to battery operated devices as its current consumption is quite high at 10mA. (There is a whole range of low-current equivalents.)
Secondly, the 555 is not a chip you add to a complex circuit as there are many other chips that can perform the task of a 555 and you will have additional gates within the chip for other sections of the circuit. The 74c14 is an example. It has 6 Schmitt trigger gates and each gate can be wired as an oscillator or delay and the chip takes less than 1mA.
Before designing a circuit around a 555, you should look at our eBook: 100 IC Circuits. It has many "building Blocks" to help you design your own circuits.**

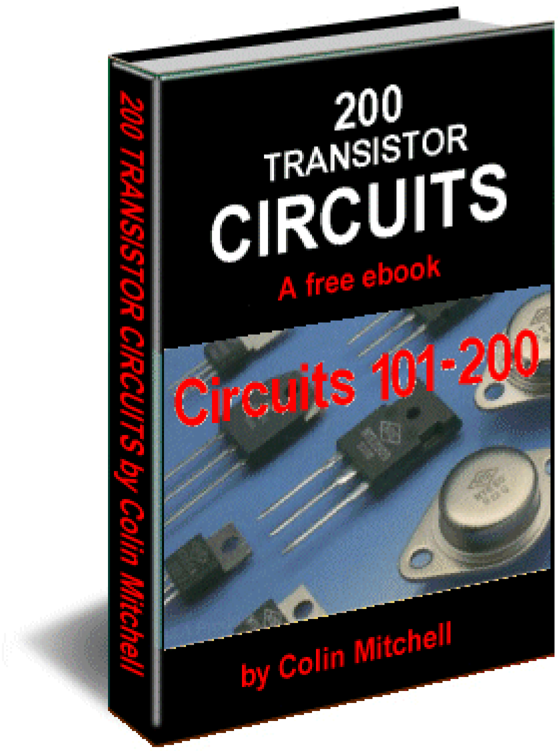


If 3rd band is gold, Divide by 10
If 3rd band is silver, Divide by 100
(to get 0.22ohms etc)

ROW	SILVER	GOLD	BLACK	BROWN	RED	ORANGE	YELLOW	GREEN
1-	R10	1R0	10R	100R	1K0	10K	100K	1M0
2-	R11	1R1	11R	110R	1K1	11K	110K	1M1
3-	R12	1R2	12R	120R	1K2	12K	120K	1M2
4-	R13	1R3	13R	130R	1K3	13K	130K	1M3
5-	R15	1R5	15R	150R	1K5	15K	150K	1M5
6-	R16	1R6	16R	160R	1K6	16K	160K	1M6
7-	R18	1R8	18R	180R	1K8	18K	180K	1M8
8-	R20	2R0	20R	200R	2K0	20K	200K	2M0
9-	R22	2R2	22R	220R	2K2	22K	220K	2M2
10-	R24	2R4	24R	240R	2K4	24K	240K	2M4
11-	R27	2R7	27R	270R	2K7	27K	270K	2M7
12-	R30	3R0	30R	300R	3K0	30K	300K	3M0
13-	R33	3R3	33R	330R	3K3	33K	330K	3M3
14-	R36	3R6	36R	360R	3K6	36K	360K	3M6
15-	R39	3R9	39R	390R	3K9	39K	390K	3M9
16-	R43	4R3	43R	430R	4K3	43K	430K	4M3
17-	R47	4R7	47R	470R	4K7	47K	470K	4M7
18-	R51	5R1	51R	510R	5K1	51K	510K	5M1
19-	R56	5R6	56R	560R	5K6	56K	560K	5M6
20-	R62	6R2	62R	620R	6K2	62K	620K	6M2
21-	R68	6R8	68R	680R	6K8	68K	680K	6M8
22-	R75	7R5	75R	750R	7K5	75K	750K	7M5
23-	R82	8R2	82R	820R	8K2	82K	820K	8M2
24-	R91	9R1	91R	910R	9K1	91K	910K	9M1
								10M (BLUE)

COLOR CODES FOR THE WHOLE E12/E24 RANGE OF RESISTORS

The twelve odd rows - 1, 3, 5... - represent values available in the E12 range only, plus 10M



Talking Electronics

See TALKING ELECTRONICS WEBSITE

email Colin Mitchell: talking@tpg.com.au

INTRODUCTION

This is the second half of our **Transistor Circuits** e-book. It contains a further 100 circuits, with many of them containing one or more Integrated Circuits (ICs).
It's amazing what you can do with transistors but when Integrated Circuits came along, the whole field of electronics exploded.
IC's can handle both analogue as well as digital signals but before their arrival, nearly all circuits were analogue or very simple "digital" switching circuits.
Let's explain what we mean.
The word analogue is a waveform or signal that is changing (increasing and decreasing) at a constant or non constant rate. Examples are voice, music, tones, sounds and frequencies. Equipment such as radios, TV's and amplifiers process analogue signals.

Then digital came along.
Digital is similar to a switch turning something on and off.
The advantage of digital is two-fold.
Firstly it is a very reliable and accurate way to send a signal. The signal is either HIGH or LOW (ON or OFF). It cannot be half-on or one quarter off.
And secondly, a circuit that is ON, consumes the least amount of energy in the controlling device. In other words, a transistor that is fully turned ON and driving a motor, dissipates the least amount of heat. If it is slightly turned ON or nearly fully turned ON, it gets very hot.
And obviously a transistor that is not turned on at all will consume no energy.
A transistor that turns ON fully and OFF fully is called a SWITCH.
When two transistors are cross-coupled in the form of a flip flop, any pulses entering the circuit cause it to flip and flop and the output goes HIGH on every second pulse. This means the circuit halves the input pulses and is the basis of counting or dividing.
Digital circuits also introduce the concept of two inputs creating a HIGH output when both are HIGH and variations of this.
This is called "logic" and introduces terms such as "Boolean algebra" and "gates."
Integrated Circuits started with a few transistors in each "chip" and increased to whole mini or micro computers in a single chip. These chips are called Microcontrollers and a single chip with a few surrounding components can be programmed to play games, monitor heart-rate and do all sorts of amazing things.
Because they can process information at high speed, the end result can appear to have intelligence and this is where we are heading: **AI** (Artificial Intelligence).

But let's crawl before we walk and come to understand how to interface some of these chips to external components.
In this Transistor Circuits ebook, we have presented about 100 interesting circuits using transistors and chips.
In most cases the IC will contain 10 - 100 transistors, cost less than the individual components and take up much less board-space. They also save a lot of circuit designing and quite often consume less current than discrete components.
In all, they are a fantastic way to get something working with the least componentry.
A list of of Integrated Circuits (Chips) is provided at the end of this book to help you identify the pins and show you what is inside the chip.
Some of the circuits are available from Talking Electronics as a kit, but others will have to be purchased as individual components from your local electronics store.
Electronics is such an enormous field that we cannot provide kits for everything.
But if you have a query about one of the circuits, you can contact me.

Colin Mitchell
TALKING ELECTRONICS.
talking@tpg.com.au

To save space we have not provided lengthy explanations of how the circuits work. This has already been covered in TALKING ELECTRONICS Basic Electronics Course, and can be obtained on a CD for $10.00 (posted to anywhere in the world)
See Talking Electronics website for more details:
http://www.talkingelectronics.com

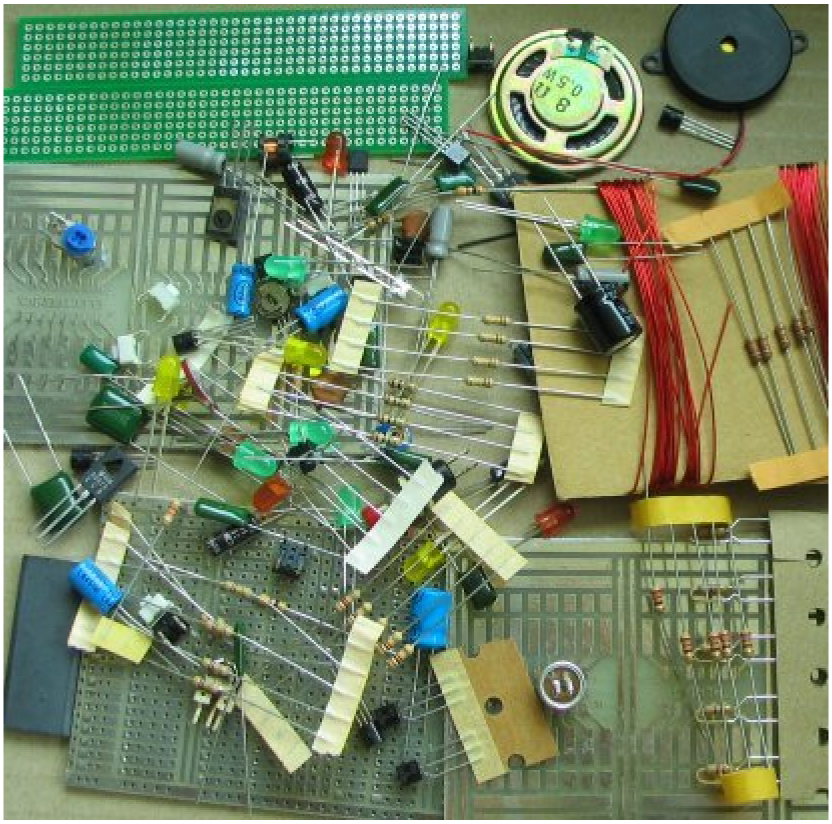
KIT OF PARTS

Talking Electronics supplies a kit of parts that can be used to build the majority of the circuits in this book.
The kit costs $15.00 plus postage.

The kit contains the following components:
(plus **extra** 30 resistors and 10 capacitors for experimenting), plus:

3 - 47R
5 - 220R
5 - 470R
5 - 1k
5 - 4k7
5 - 10k
2 - 33k
4- 100k
4 - 1M
1 - 10k mini pot
1 - 100k mini pot
2 - 10n
2 - 100n
5 - 10u electrolytics
5- 100u electrolytics
5 - 1N4148 signal diodes
6 - BC547 transistors
2 - BC557 transistors
1 - BC338 transistor
3 - BD679 Darlington transistors
5 - red LEDs
5 - green LEDs
5 - orange LEDs
2 - superbright WHITE LEDs - 20,000mcd
1 - 3mm or 5mm flashing LED
1 - mini 8R speaker
1 - mini piezo
1 - LDR (Light Dependent Resistor)
1 - electret microphone
1m - 0.25mm wire
1m - 0.5mm wire
1 - 10mH inductor
1 - push button
5 - tactile push buttons
1 - **Experimenter Board** (will take 8, 14 and 16 pin chips)
5 - mini Matrix Boards: 7 x 11 hole,
11 x 15 hole, 6 x 40 hole, surface-mount 6 x 40 hole board or others.

Photo of kit of components.
Each batch is slightly different:



In many cases, a resistor or capacitor not in the kit, can be created by putting two resistors or capacitors in series or parallel or the next higher or lower value can be used.

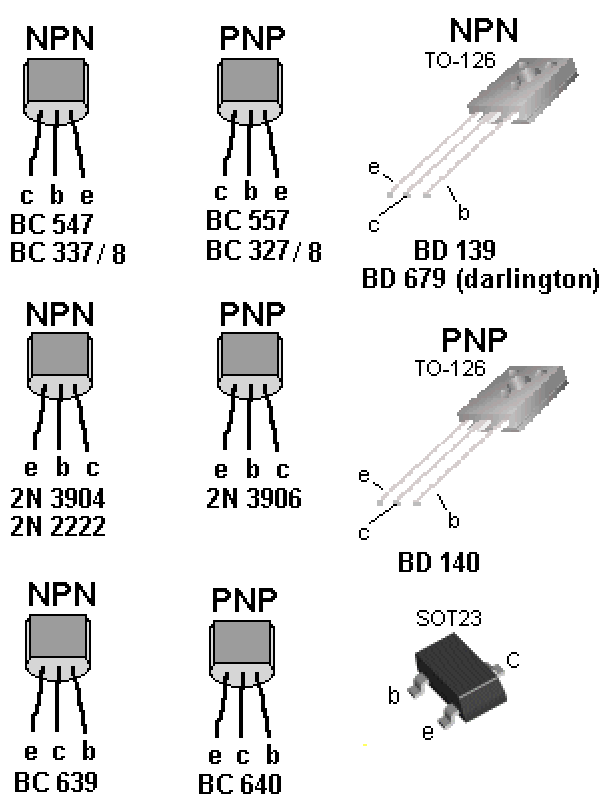
MORE INTRO

There are two ways to learn electronics.
One is to go to school and study theory for 4 years and come out with all the theoretical knowledge in the world but almost no practical experience.
We know this type of person. We employed them (for a few weeks!). They think everything they design WILL WORK because their university professor said so.
The other way is to build circuit after circuit and get things to work. You may not know the in-depth theory of how it works but trial and error gets you there.
We know. We employed this type of person for up to 12 years.
I am not saying one is better than the other but most electronics enthusiasts are not "book worms" and anyone can succeed in this field by constantly applying themselves with "constructing projects." You actually learn 10 times faster by applying yourself and we have had technicians repairing equipment after only a few weeks on the job.
It would be nothing for an enthusiast to build 30 - 40 circuits from our previous Transistor eBook and a similar number from this book. Many of the circuits are completely different to each other and all have a building block or two that you can learn from.
Electronics enthusiasts have an uncanny understanding of how a circuit works and if you have this ability, don't let it go to waste.
Electronics will provide you a comfortable living for the rest of your life and I mean this quite seriously. The market is very narrow but new designs are coming along all the time and new devices are constantly being invented and more are always needed.
Once you get past this eBook of "Chips and Transistors" you will want to investigate microcontrollers and this is when your options will explode.
You will be able to carry out tasks you never thought possible, with a chip as small as 8 pins and a few hundred lines of code.
As I say in my speeches. What is the difference between a "transistor man" and a "programmer?" TWO WEEKS!
In two weeks you can start to understand the programming code for a

microcontroller and perform simple tasks such as flashing a LED and produce sounds and outputs via the press of a button.
All these things are covered on Talking Electronics website and you don't have to buy any books or publications. Everything is available on the web and it is instantly accessible. That's the beauty of the web.
Don't think things are greener on the other side of the fence, by buying a text book. They aren't. Everything you need is on the web AT NO COST.
The only thing you have to do is build things. If you have any technical problem at all, simply email Colin Mitchell and any question will be answered. Nothing could be simpler and this way we guarantee you SUCCESS. Hundreds of readers have already emailed and after 5 or more emails, their circuit works. That's the way we work. One thing at a time and eventually the fault is found.
If you think a circuit will work the first time it is turned on, you are fooling yourself.
All circuits need corrections and improvements and that's what makes a good electronics person. Don't give up. How do you think all the circuits in these eBooks were designed? Some were copied and some were designed from scratch but all had to be built and adjusted slightly to make sure they worked perfectly.
I don't care if you use bread-board, copper strips, matrix board or solder the components in the air as a "bird's nest." You only learn when the circuit gets turned on and WORKS!
In fact the rougher you build something, the more you will guarantee it will work when built on a printed circuit board.
However, high-frequency circuits (such as 100MHz FM Bugs) do not like open layouts and you have to keep the construction as tight as possible to get them to operate reliably.
In most other cases, the layout is not critical.

TRANSISTORS

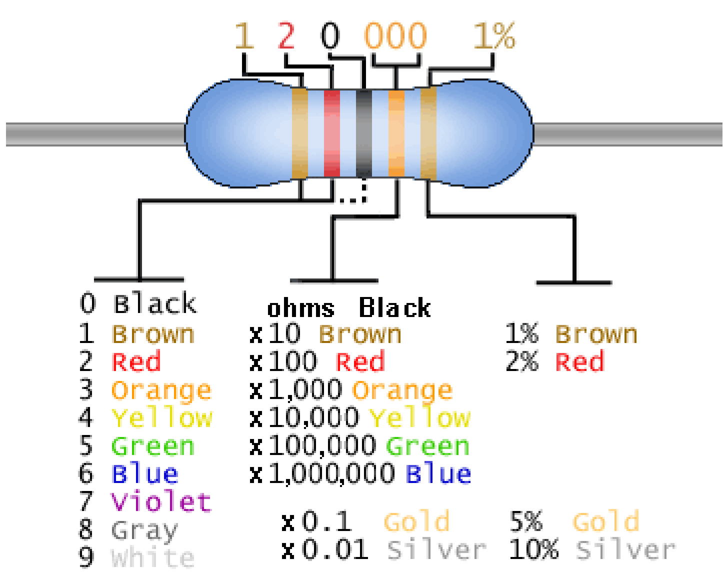
Most of the transistors used in our circuits are BC 547 and BC 557. These are classified as "universal" or "common" NPN and PNP types with a voltage rating of about 25v, 100mA collector current and a gain of about 100. Some magazines use the term "**TUP**" (for Transistor Universal PNP) or "**TUN**" (for Transistor Universal NPN). We simply use Philips types that everyone recognises. You can use almost any type of transistor to replace them and here is a list of the equivalents and pinouts:



CONTENTS red indicates 1-100 Transistor Circuits

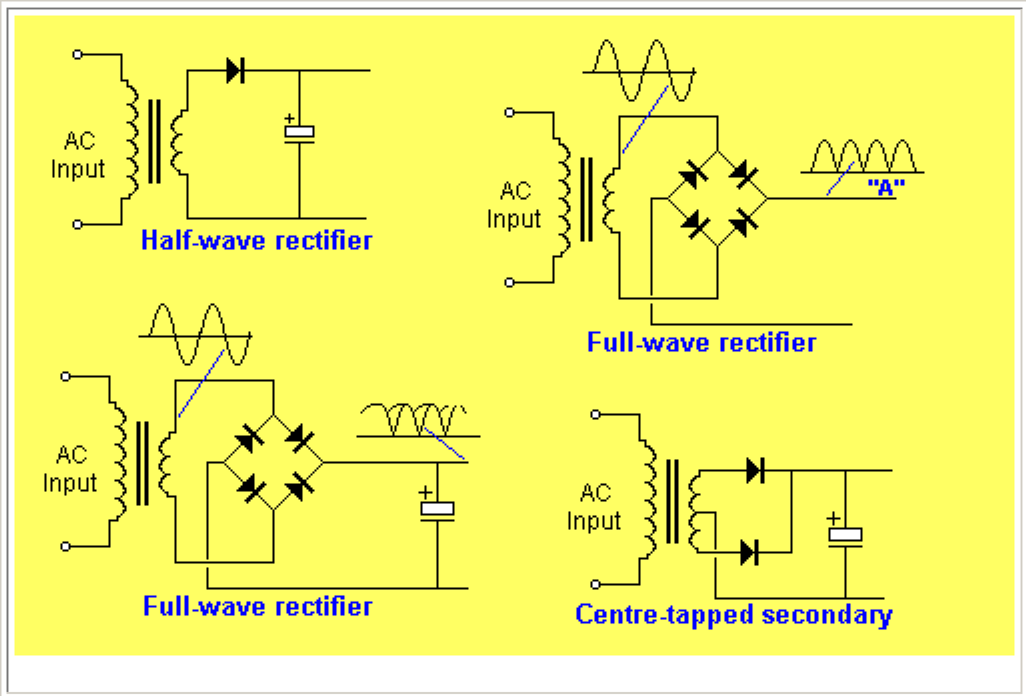
Note: **All** circuits use 1/4 watt resistors unless specified on the diagram.

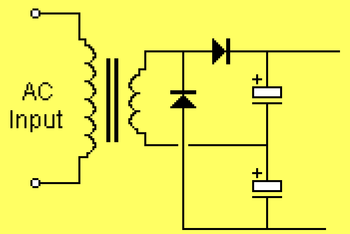
RESISTOR COLOUR CODE



RECTIFYING a Voltage

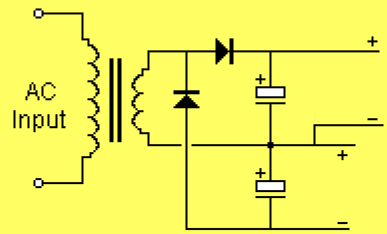
These circuits show how to change an oscillating voltage (commonly called AC) to DC. The term AC means Alternating Current but it really means Alternating Voltage as the rising and falling voltage produces an increasing and decreasing current. The term DC means Direct Current but it actually means Direct or unchanging Voltage.
The output of the following circuits will not be pure DC (like that from a battery) but will contain ripple. Ripple is reduced by adding a capacitor (electrolytic) to the output.


AC
Input
Half-wave rectifier
AC
Input
"A"
Full-wave rectifier
AC
Input
Full-wave rectifier
AC
Input
Centre-tapped secondary



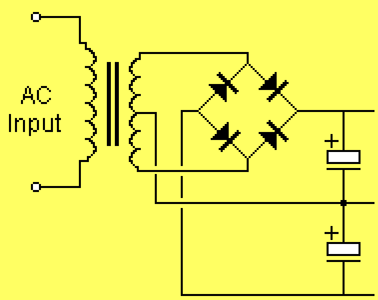
Full-wave voltage doubler

Each section is half-wave supplied. The circuit uses both positive and negative parts of the waveform

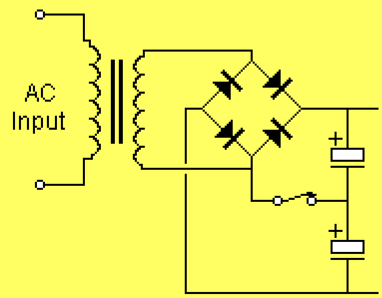


Dual Power Supply

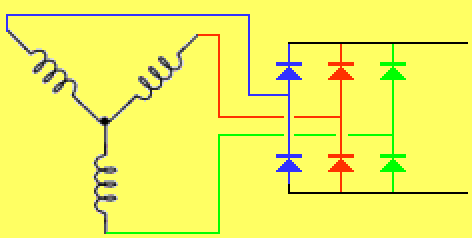
using a single secondary



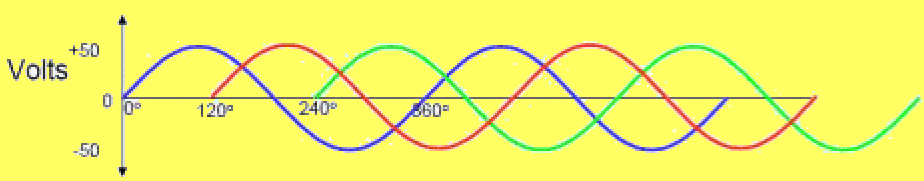
Dual Power Supply
using a
Centre-tapped secondary

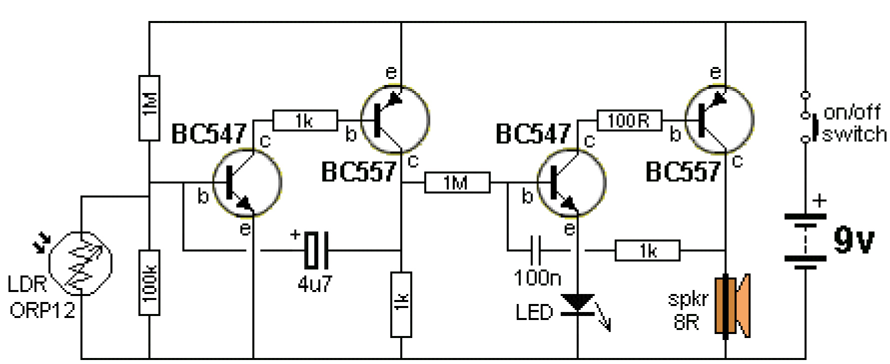


This clever circuit is a voltage doubler when the switch is closed



3-phase alternator such as car alternator or windmill

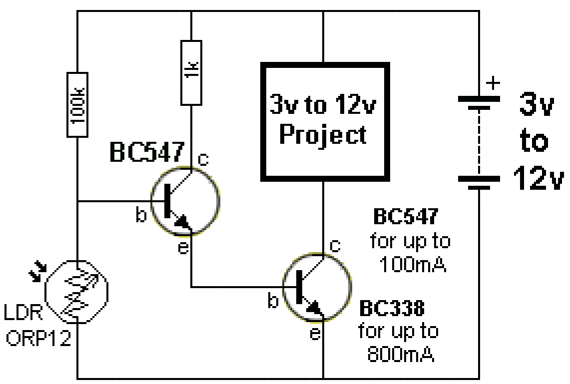




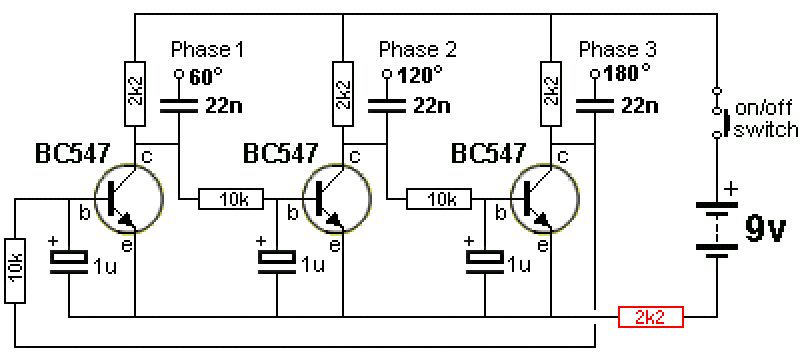
DARK DETECTOR with beep-beep-beep Alarm

This circuit detects darkness and produces a beep-beep-beep alarm. The first two transistors form a high-gain amplifier with feedback via the 4u7 to produce a low-frequency oscillator. This provides voltage for the second oscillator (across the 1k resistor) to drive a speaker.

Project can turn ON when DARK

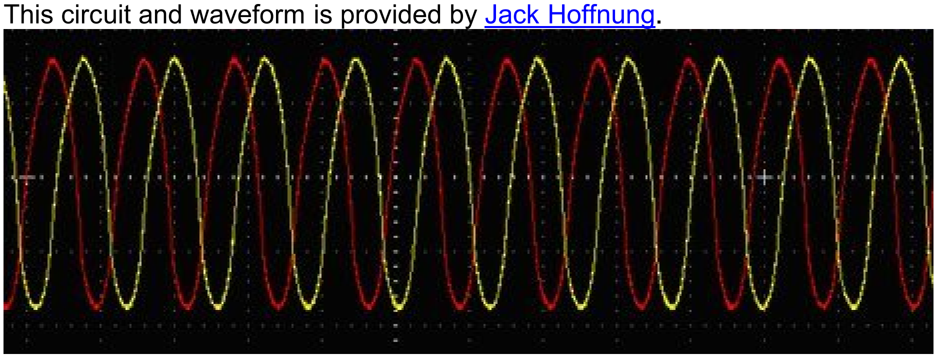


This circuit detects darkness and allows the project to turn on. The project can be any circuit that operates from 3v to 12v.
The components have been chosen for a 6v project that requires 500mA.

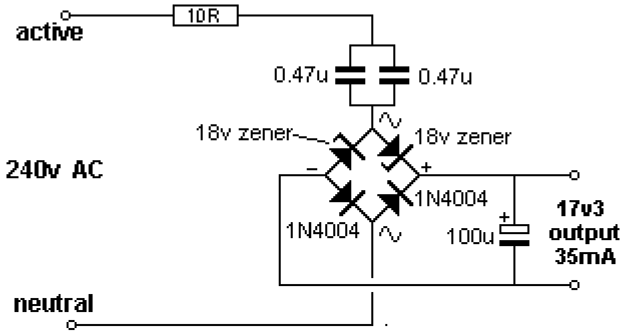


3-PHASE SINEWAVE GENERATOR

This circuit produces a sinewave and each phase can be tapped at the point shown. The secret to producing a good waveform is the addition of the 2k2 resistor in the 0v rail
This circuit and waveform is provided by Jack Hoffnung.



Two of the three waveforms - we only have dual trace CRO's !!!!



TRANSFORMERLESS POWER SUPPLY

This clever design uses 4 diodes in a bridge to produce a fixed voltage power supply capable of supplying 35mA.
All diodes (every type of diode) are zener diodes. They all break down at a particular voltage. The fact is, a power diode breaks down at 100v or 400v and its zener characteristic is not useful.
But if we put 2 zener diodes in a bridge with two ordinary power diodes, the bridge will break-down at the voltage of the zener. This is what we have done. If we use 18v zeners, the output will be 17v4.
When the incoming voltage is positive at the top, the left zener provides 18v limit (and the other zener produces a drop of 0.6v) This allows the right zener to pass current just like a normal diode. The output is 17v4. The same with the other half-cycle.
The current is limited by the value of the X2 capacitors and this is 7mA for each 100n when in full-wave (as per this circuit). We have 1u capacitance. Theoretically the circuit will supply 70mA but we found it will only deliver 35mA before the output drops. The capacitors should comply with X1 or X2 class. The 10R is a safety-fuse resistor.
The problem with this power supply is the "live" nature of the negative rail. When the power supply is connected as shown, the negative rail is 0.7v above neutral. If the mains is reversed, the negative rail is 340v (peak) above neutral and this will kill you as the current will flow through the diode and be lethal. You need to touch the negative rail (or the positive rail) and any earthed device such as a toaster to get killed. The only solution is the project being powered must be totally enclosed in a box with no outputs.
A **TRANSFORMERLESS POWER SUPPLY** is also called a **CAPACITOR FED POWER SUPPLY**.
It is very dangerous.
Here's why:
A **Capacitor Power Supply** uses a capacitor to interface between a “high voltage supply” and a low voltage – called THE POWER SUPPLY.
In other words a capacitor is placed between a “high voltage supply” we call THE MAINS (between 110v and 240v) and a low voltage that may be 9v to 12v.
Even though a capacitor consists of two plates that do not touch each other, a **Capacitor Power Supply** is a very dangerous project, for two reasons.
You may not think electricity can pass though a capacitor because it consists of plates that do not touch each other.
But a capacitor works in a slightly different way. A capacitor connected to the mains works like this:
Consider a magnet on one side of a door. On the other side we have a sheet of metal. As you slide the magnet up the door, the sheet of metal rises too.
The same with a capacitor. As the voltage on one side of the capacitor rises, the voltage on the other side is “pulled out of the ground” - and it rises too.
If you stand on the ground and hold one lead of the capacitor and connect the other to the active side of the “mains,” the capacitor will “pull” 120v or 240v “out of the ground” and you will get a shock.
Don’t ask “how” or “why.” This is just the simplest way to describe how you get a shock via a capacitor that consists of two plates.
If the capacitor “shorts” between the two plates, the 120v or 240v will be delivered to your power supply and create damage.
Secondly, if any of the components in your power supply become open-circuit, the voltage on the power supply will increase.
But the most dangerous feature of this type of power supply is reversal of the mains leads.
The circuit is designed so that the neutral lead goes to the earth of your power supply.
This means the active is connected to the capacitor.
Now, the way the active works is this:
The active lead rises 120x 1.4 = 180v in the positive direction and then drops to 180v in the opposite direction. In other words it is 180v higher than the neutral line then 180v lower than the neutral.
For 240v mains, this is 325v higher then 325v lower.
The neutral is connected to the chassis of your project and if you touch it, nothing will happen. It does not rise or fall.
But suppose you connect the power leads around the wrong way.
The active is now connected to the chassis and if you touch the chassis and a water pipe, you will get a 180v or 345v shock.
That’s why a CAPACITOR-FED power supply must be totally isolated.
Now we come to the question: How does a capacitor produce a 12v power supply?
When a capacitor is connected to the mains, one lead is rising and falling.
Depending on the size of the capacitor, it will allow current to flow into and out of the other lead.
If the capacitor is a large value, a high current will flow into and out of the lead. In addition, a high voltage will allow a higher current to flow.
This current is “taken out of the ground” and “flows back into the ground.”
It does not come from the mains. The mains only: “influences” the flow of current.
Thus we have a flow of current into and out of the capacitor.

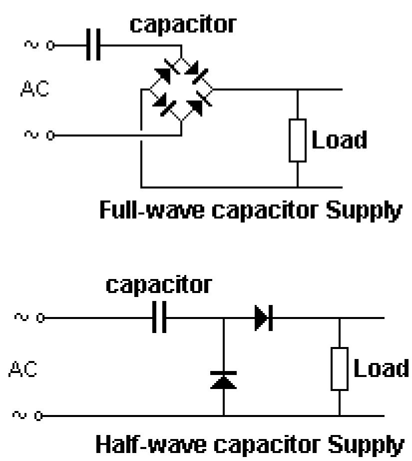
If you put a resistor between the capacitor and "ground," the amount of current that will flow, depends on 3 things, the amplitude of the voltage, the size of the capacitor and the speed of the rise and fall.
When current flows through a resistor, a voltage develops across the resistor and if we select the correct value of resistance, we will get a 12v power supply.

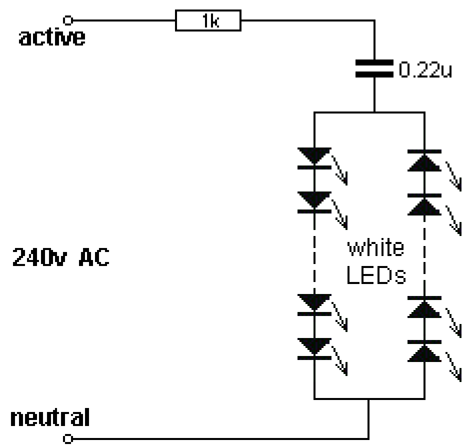
THE OUTPUT VOLTAGE

The **OUTPUT VOLTAGE** of all transformerless power supplies will be about 50% HIGHER than the mains voltage if a LOAD is not connected. That's RIGHT: The output of a 120v CAPACITOR POWER SUPPLY (transformerless power supply) will be about 180v and a 240v mains transformerless power supply will be about 345v.

How do you get a 12v or 24v supply????

It works like this: The transformerless power supply is a CURRENT-DELIVERED power supply. In other words we have to talk about CURRENT-VALUES and not voltages.
For a bridge circuit (called a full-wave design) it will deliver 7mA for each 100n. Suppose we have 220n. We have 15mA available.
We take the 15mA and say: How many volts will develop across a 100R load? The answer = 0.015 x 100 = 15v. I f we use 82R the voltage will be about 12v. If we use 220R the voltage will be 33v. That's how the output voltage is developed.
If you add another 220n across the 220n, the voltages will be DOUBLE. It's as simple as that.



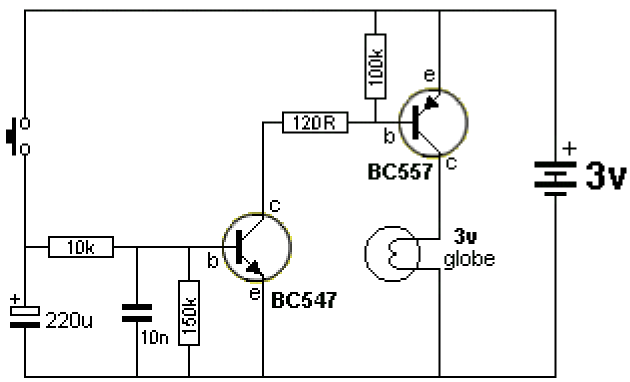


LEDs on 240v

I do not like any circuit connected directly to 240v mains. However Christmas tress lights have been connected directly to the mains for 30 years without any major problems.
Insulation must be provided and the lights (LEDs) must be away from prying fingers.
You need at least 50 LEDs in each string to prevent them being damaged via a surge through the 1k resistor - if the circuit is turned on at the peak of the waveform. As you add more LEDs to each string, the current will drop a very small amount until eventually, when you have 90 LEDs in each string, the current will be zero.
For 50 LEDs in each string, the total characteristic voltage will be 180v so that the peak voltage will be 330v - 180v = 150v. Each LED will see less than 7mA peak during the half-cycle they are illuminated. The 1k resistor will drop 7v - since the RMS current is 7mA (7mA x 1,000 ohms = 7v).
No rectifier diodes are needed. The LEDs are the "rectifiers." Very clever. You must have LEDs in both directions to charge and discharge the capacitor. The resistor is provided to take a heavy surge current through one of the strings of LEDs if the circuit is switched on when the mains is at a peak.
This can be as high as 330mA if only 1 LED is used, so the value of this resistor must be adjusted if a small number of LEDs are used. The LEDs above detect peak current.
A 100n cap will deliver 7mA RMS or 10mA peak in full wave or 3.5mA RMS (10mA peak for half a cycle) in half-wave. (when only 1 LED is in each string)**.**

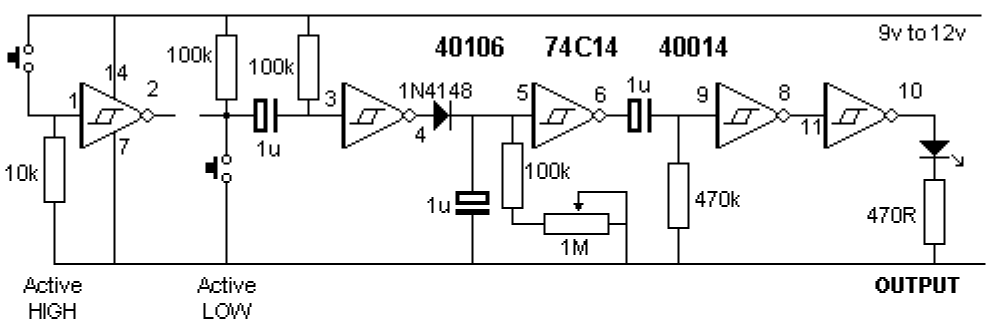
The current-capability of a capacitor needs more explanation. In the diagram on the left we see a capacitor feeding a full-wave power supply. This is exactly the same as the **LEDs on 240v** circuit above. Imagine the LOAD resistor is removed. Two of the diodes will face down and two will face up. This is exactly the same as the LEDs facing up and facing down in the circuit above. The only difference is the mid-point is joined. Since the voltage on the mid-point of one string is the same as the voltage at the mid-point of the other string, the link can be removed and the circuit will operate the same.
This means each 100n of capacitance will deliver 7mA RMS (10mA peak on each half-cycle).
In the half-wave supply, the capacitor delivers 3.5mA RMS (10mA peak on each half-cycle, but one half-cycle is lost in the diode) for each 100n to the load, and during the other half-cycle the 10mA peak is lost in the diode that discharges the capacitor.

You can use any LEDs and try to keep the total voltage-drop in each string equal. Each string is actually working on DC. It's not constant DC but varying DC. In fact is it zero current for 1/2 cycle then nothing until the voltage rises above the total characteristic voltage of all the LEDs, then a gradual increase in current over the remainder of the cycle, then a gradual decrease to zero over the falling portion of the cycle, then nothing for 1/2 cycle. Because the LEDs turn on and off, you may observe some flickering and that's why the two strings should be placed together.



BOOK LIGHT

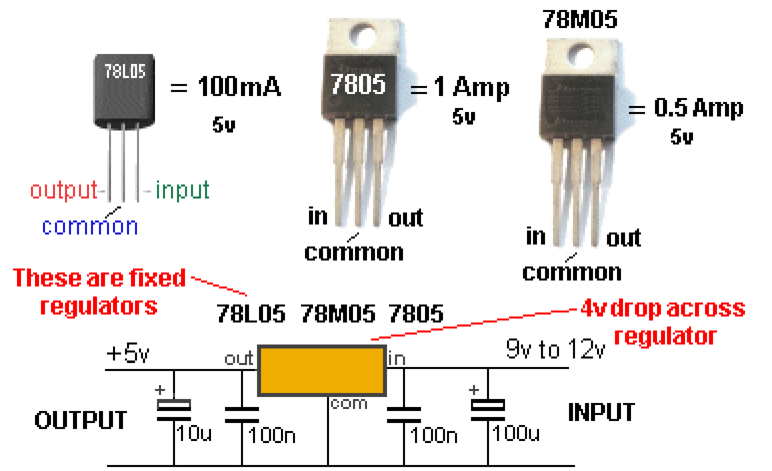
This circuit keeps the globe illuminated for a few seconds after the switch is pressed.
There is one minor fault in the circuit. The 10k should be increased to 100k to increase the "ON" time.
The photo shows the circuit built with surface-mount components:



CAMERA ACTIVATOR

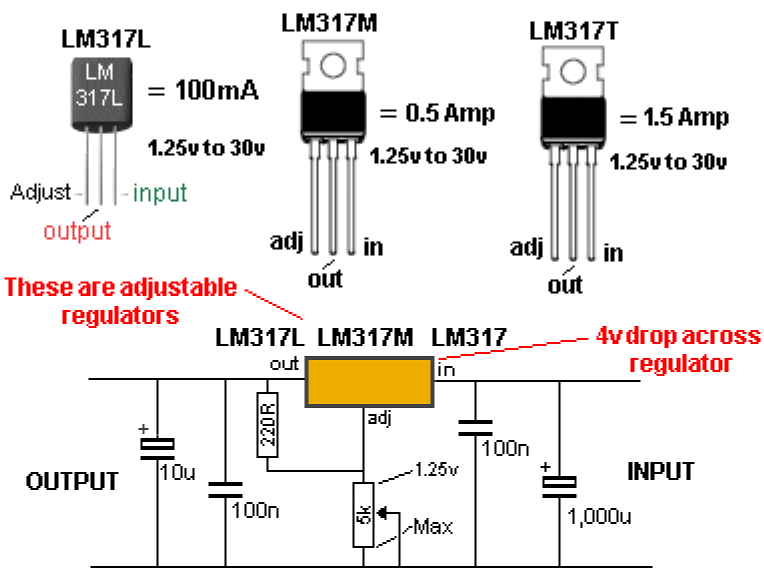
This circuit was designed for a customer who wanted to trigger a camera after a short delay.
The output goes HIGH about 2 seconds after the switch is pressed. The LED turns on for about 0.25 seconds.
The circuit will accept either active HIGH or LOW input and the switch can remain pressed and it will not upset the operation of the circuit. The timing can be changed by adjusting the 1M trim pot and/or altering the value of the 470k.

POWER SUPPLIES - FIXED:



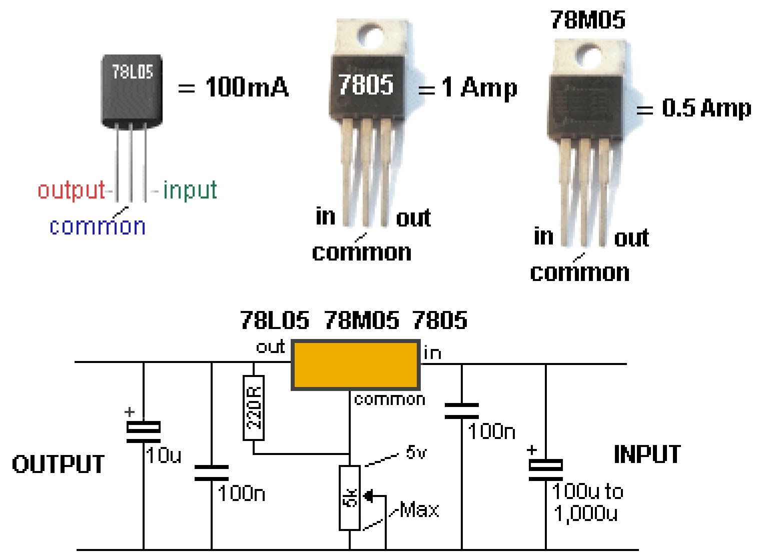
A simple power supply can be made with a component called a "3-pin regulator or 3-terminal regulator" It will provide a very low ripple output (about 4mV to 10mV provided electrolytics are on the input and output.
The diagram above shows how to connect a regulator to create a power supply. The 7805 regulators can handle 100mA, 500mA and 1 amp, and produce an output of 5v, as shown.
These regulators are called **linear regulators** and drop about 4v across them - minimum. If the current flow is 1 amp, 4watts of heat must be dissipated via a large heatsink. If the output is 5v and input 12v, 7volts will be dropped across the regulator and 7watts must be dissipated.

POWER SUPPLIES - ADJUSTABLE:



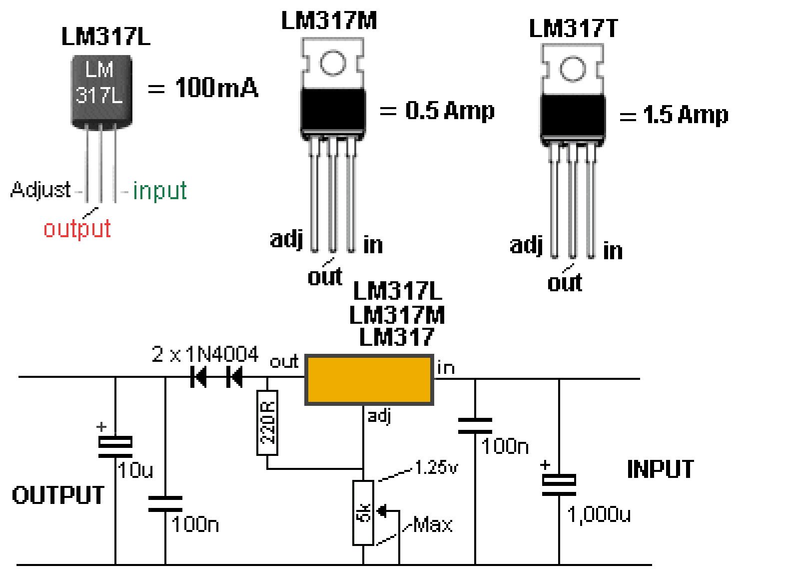
The LM317 regulators are adjustable and produce an output from 1.25 to about 35v. The LM317T regulator will deliver up to 1.5amp.

POWER SUPPLIES - ADJUSTABLE using 7805:



The 7805 range of regulators are called "fixed regulators" but they can be turned into adjustable regulators by "jacking-up" their output voltage. For a 5v regulator, the output can be 5v to 30v.

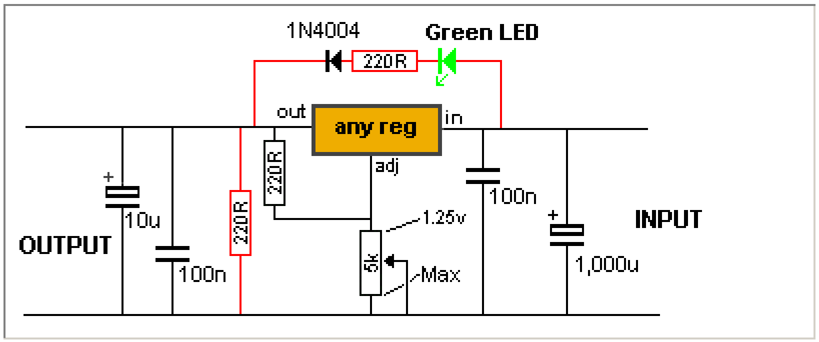
POWER SUPPLIES - ADJUSTABLE from 0v:



The LM317 regulator is adjustable from 1.25 to about 35v. To make the output 0v to 35v, two power diodes are placed as shown in the circuit. Approx 0.6v is dropped across each diode and this is where the 1.25v is "lost."

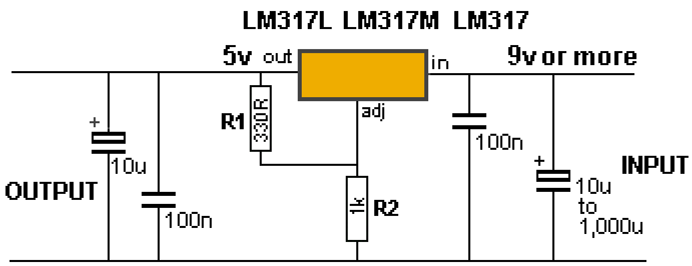
LOW INPUT VOLTAGE

This clever circuit lets you know if the voltage across the regulator drops below 2v.
This is very important when you are increasing the output voltage and the regulator SUDDENLY drops out of regulation because the voltage across it is insufficient.
This can be due to the ripple causing the problem and you will see the green LED flickering.
You can add extra diodes in series with the LED to get a safety margin of 2.6v or 3.2v The 220R on the output is only needed when the output is not loaded and the current taken by the LED needs to be brought from the 0v rail as the output does not like to dragged higher than 5v (or its present output voltage).



5v POWER SUPPLY

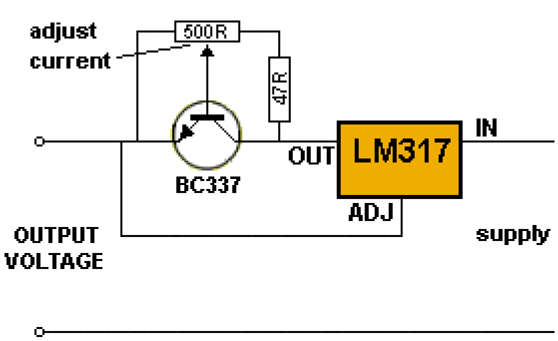
Using the the LM317 regulator to produce 5v supply (5.04v):



on-line calculator for LM317:
http://diyaudioprojects.com/Technical/Voltage-Regulator/

$$V_{out} = 1.25v\left(1 + \frac{R2}{R1}\right) + I_{adj}(R2)$$

	5.04v	9.6v	11.83v
R1	330R	330R	390R
R2	1k	2k2	3k3



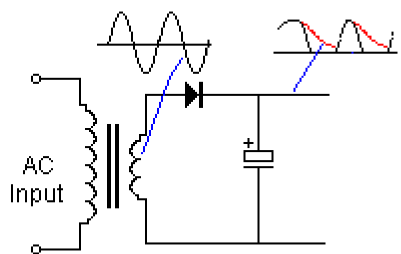
CONSTANT CURRENT

This constant current circuit can be adjusted to any value from a few milliamp to about 500mA - this is the limit of the BC337 transistor.
The circuit can also be called a current-limiting circuit and is ideal in a bench power supply to prevent the circuit you are testing from being damaged.
Approximately 4v is dropped across the regulator and 1.25v across the current-limiting section, so the input voltage (supply) has to be 5.25v above the required output voltage. Suppose you want to charge 4 Ni-Cad cells. Connect them to the output and adjust the 500R pot until the required charge-current is obtained.
The charger will now charge 1, 2, 3 or 4 cells at the same current.
But you must remember to turn off the charger before the cells are fully charged as the circuit will not detect this and over-charge the cells.
The LM 317 3-terminal regulator will need to be heatsinked.

This circuit is designed for the LM series of regulator as they have a voltage differential of 1.25v between "adj" and "out" terminals. 7805 regulators can be used but the losses in the BC337 will be 4 times greater as the voltage across it will be 5v.

THE POWER SUPPLY

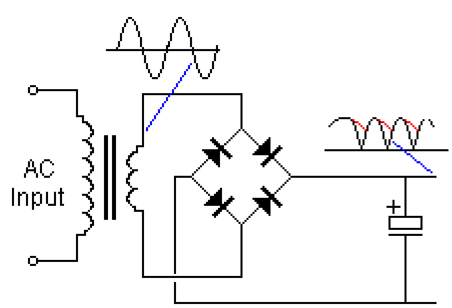
The simplest power supply is a transformer, diode and electrolytic:



Half-wave rectifier

But the ripple will be very high because only every alternate portion of the ac signal is being passed through the diode and the electrolytic (called the filter capacitor) cannot smooth the ripple very well. The result will be a loud hum if powering an amplifier.

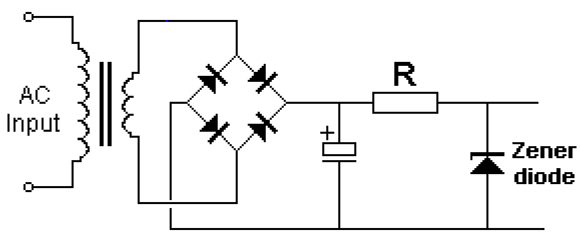
An improvement is to use a bridge rectifier. This will reduce the ripple and reduce the hum because the waveform to the electrolytic consists of pulses that are closer together and the electrolytic does not have to supply as much energy because the pulses are closer together.



Full-wave rectifier

ZENER REGULATION

The next improvement is to reduce the ripple with a zener diode. The zener diode is placed across the voltage you want to smooth and as the voltage increases, the zener diode turns ON more and additional current flows through it to the 0v rail. This reduces the voltage but the result is a smoother voltage.
This is called a SHUNT REGULATOR or ZENER SHUNT REGULATOR or ZENER DIODE STABILIZER.



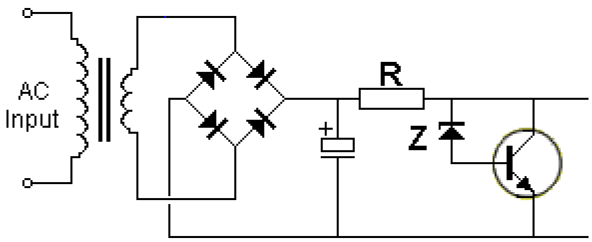
Shunt Zener Regulator

In place of a zener, we can use a transistor.

THE SHUNT TRANSISTOR

A transistor placed across the voltage to be regulated (or stabilized)

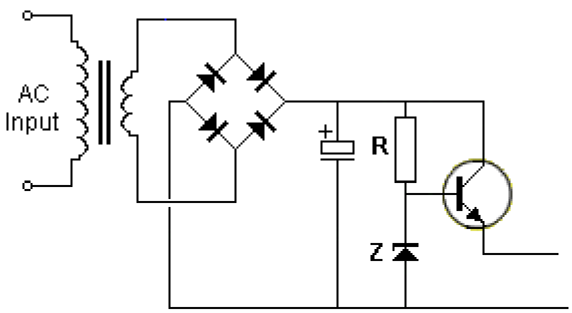
is called a SHUNT TRANSISTOR, because it shunts or sends the unwanted extra waveform to the 0v rail, and thereby smoothes the voltage.
It uses a zener to sense the voltage as in the zener regulator circuit above, but the current through the zener is less because the transistor turns ON and reduces the voltage. A lower-wattage zener diode can be used and since less current flows through it, the voltage across it will be more stable.
This arrangement is better than a zener diode regulator due the improved stability of the diode with less current flowing through it and the circuit will deliver about 100 times more current due to the inclusion of the transistor.
However, this circuit is very wasteful because the maximum current is **flowing all the time** and being sent to the 0v rail. When you add a load (such as an amplifier), the current is diverted from the shunt transistor and into the amplifier. The amplifier can only take current up to the maximum the transistor was passing to the 0v rail.



Transistor Shunt Regulator

THE PASS TRANSISTOR

A PASS TRANSISTOR is less wasteful than a SHUNT TRANSISTOR. The circuit takes almost no current (when the amplifier is not connected).
The ripple on the output is determined by the effectiveness of the zener (due to the low current is is required to pass) and the transistor (passes this voltage and) amplifies the current about 100 times.



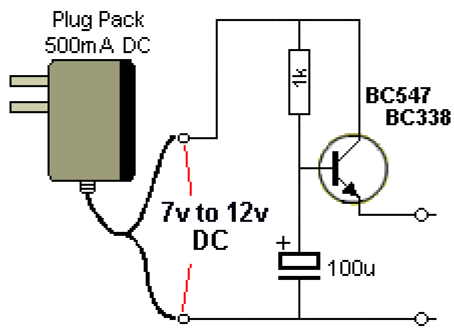
Pass Transistor Regulator

No values have been provided for these circuits are they are intended to explain **Shunt Transistor** and **Pass Transistor**. The type of transistor and value of resistor in the power line will depend on the current.

THE ELECTRONIC FILTER

Here is a simple circuit to reduce the ripple from a power supply by a factor of about 100. This means a 20mV ripple will be 0.2mV and will not be noticed. This is important when you are powering an FM bug from a plug pack. The background hum is annoying and very difficult to remove with electrolytics. This circuit is the answer. The 1k and 100u form a filter that makes the 100u **one hundred times** more effective than if placed directly on the supply-line. The transistor detects the voltage on the base and also detects the very small ripple.
As current is taken by the load, about 100th of this current is required by the base and if the

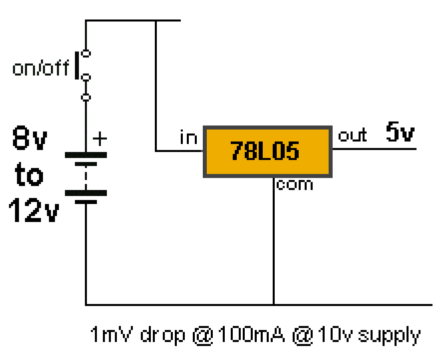
load current is 100mA, the current into the base will be 1mA and one volt will be dropped across the 1k resistor.
The circuit is suitable for up to 100mA. A power transistor can be used, but the 1k will have to be reduced to 220R for 500mA output. The output of the circuit is about 2v less than the output of the plug pack.
By adding a zener across the electro, the output voltage will remain much more constant (fixed). If a zener is not added, the output voltage will drop as the current increases due to a factor called REGULATION. This is the inability of the small transformer to provide a constant voltage. The addition of the 3 components only reduces the RIPPLE portion of the voltage - and does not change the fact that the voltage will droop when current is increased. It requires a zener to fix this problem.
This circuit can also be called: RIPPLE SUPPRESSOR, RIPPLE REDUCER or CAPACITANCE MULTIPLIER. The 100u can be increased to 470u or 1,000u.

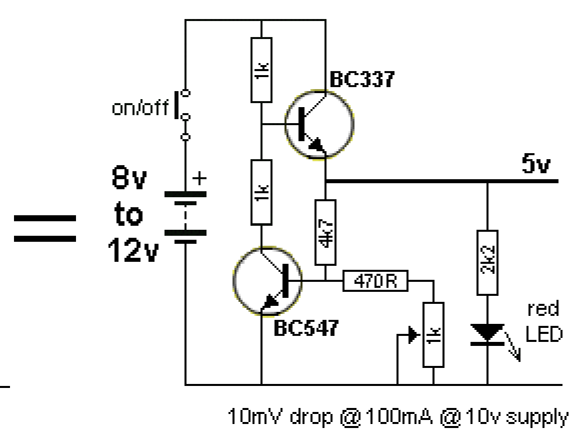


An ELECTRONIC FILTER

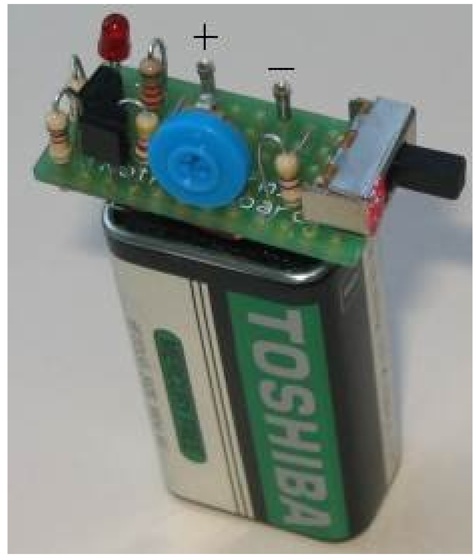
5v FROM OLD CELLS - circuit 1

This circuit takes the place of a 78L05 3-terminal regulator. It produces a constant 5v @ 100mA. You can use any old cells and get the last of their energy. Use an 8-cell holder. The voltage from 8 old cells will be about 10v and the circuit will operate down to about 7.5v. The regulation is very good at 10v, only dropping about 10mV for 100mA current flow (the 78L05 has 1mV drop). As the voltage drops, the output drops from 5v on no-load to 4.8v and 4.6v on 100mA current-flow. The pot can be adjusted to compensate for the voltage-drop. This type of circuit is called a LINEAR REGULATOR and is not very efficient (about 50% in this case). See circuit 2 below for BUCK REGULATOR circuit (about 85% efficient).



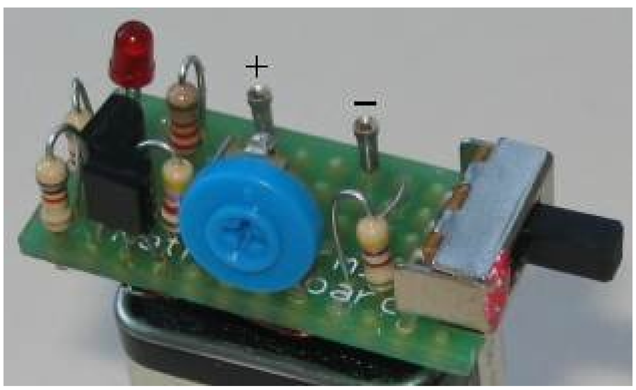


The regulator connected to a 12v battery pack



The regulator connected to a 9v battery

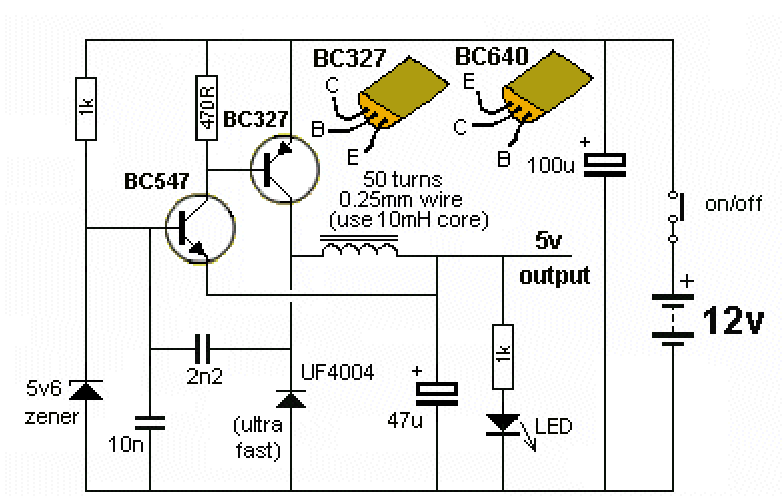
The battery snap plugs into the pins on the 5v regulator board with the red lead going to the negative output of the board as the battery snap is now DELIVERING voltage to the circuit you are powering.

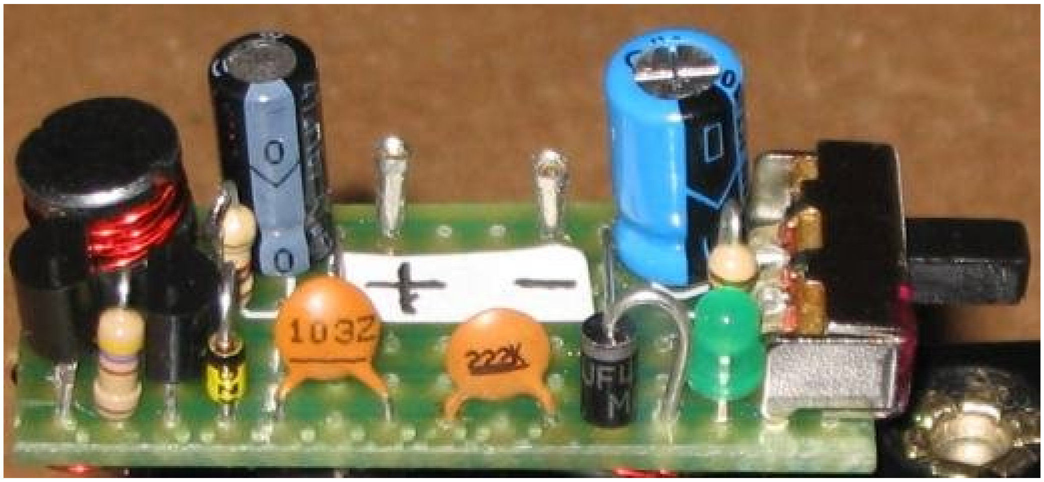


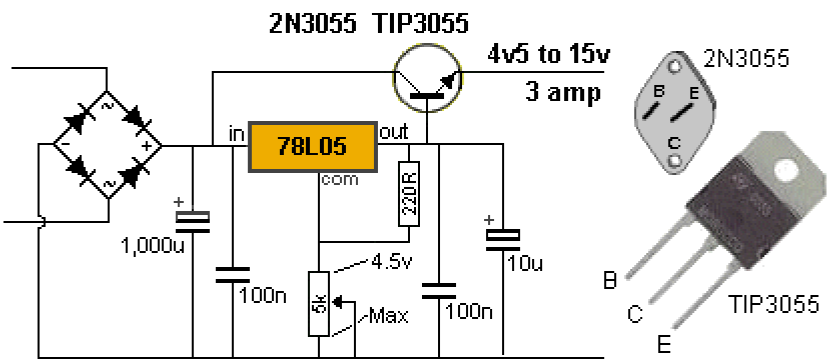
A close-up of the regulator module

5v FROM OLD CELLS - circuit 2

This circuit is a BUCK REGULATOR. It can take the place of a 78L05 3-terminal regulator, but it is more efficient. It produces a constant 5v @ up to 200mA. You can use any old cells and get the last of their energy. Use an 8-cell holder. The voltage from 8 old cells will be about 10v and the circuit will operate down to about 7.5v. The regulation is very good at 10v, only dropping 10mV for up to 200mA output.

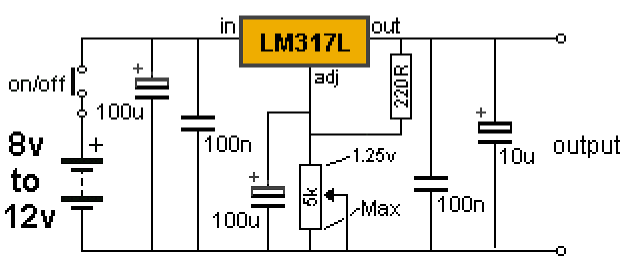






INCREASING THE OUTPUT CURRENT

The output current of all 3-terminal regulators can be increased by including a pass transistor. This transistor simply allows the current to flow through the collector-emitter leads.
The output voltage is maintained by the 3-terminal regulator but the current flows through the "pass transistor." This transistor is a power transistor and must be adequately heatsinked.
Normally a 2N3055 or TIP3055 is used for this application as it will handle up to 10 amps and creates a 10 amp power supply. The regulator can be 78L05 as all the current is delivered by the pass transistor.

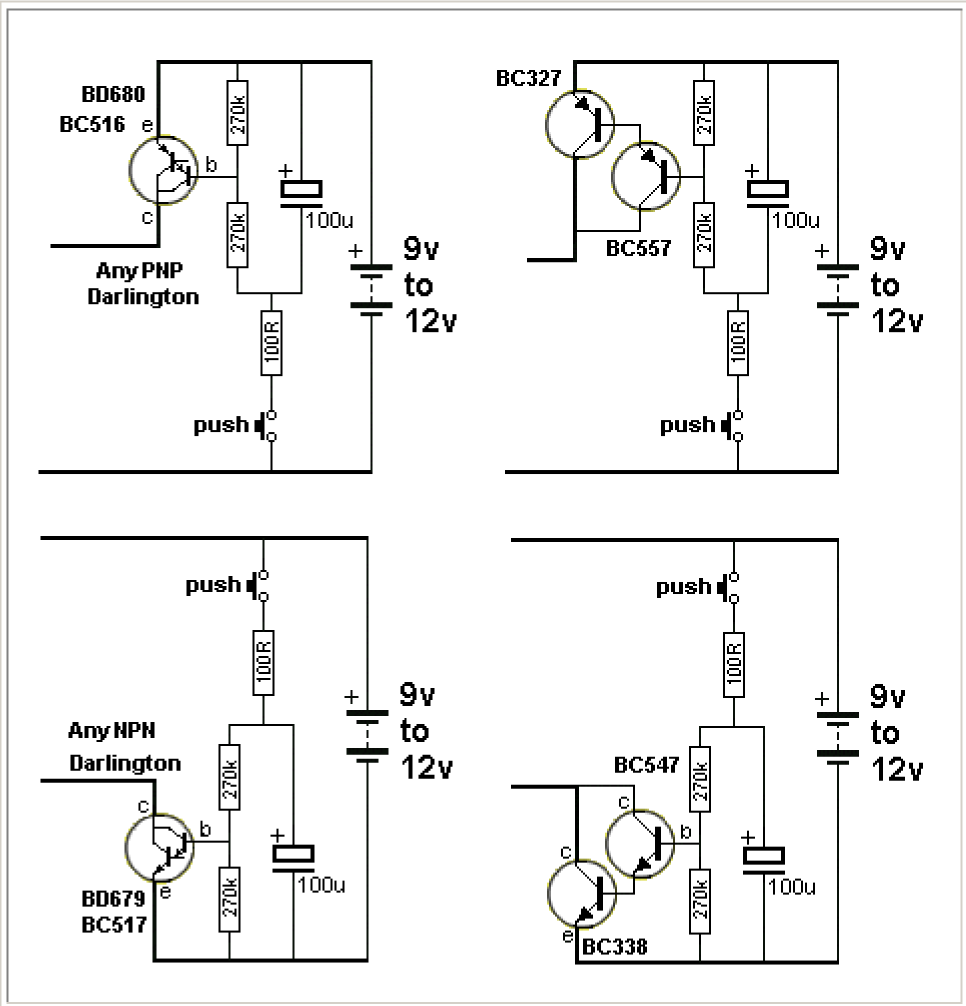


SOFT START

The output voltage of a 3-terminal regulator can be designed to rise slowly. This has very limited application as many circuits do not like this.

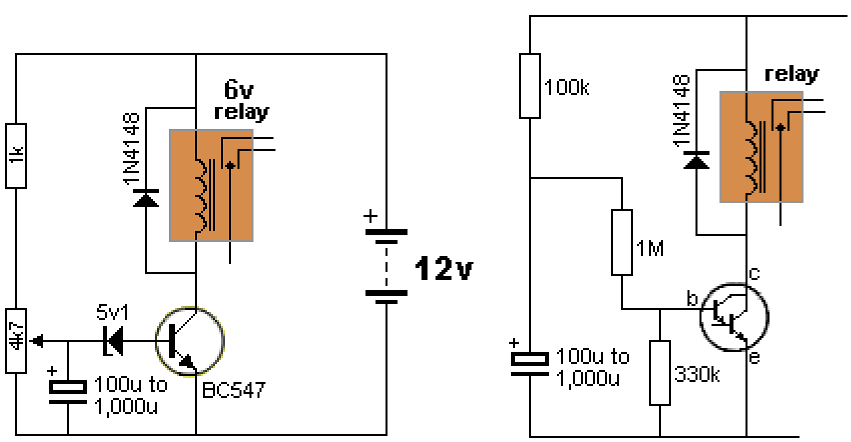
TURN-OFF DELAY

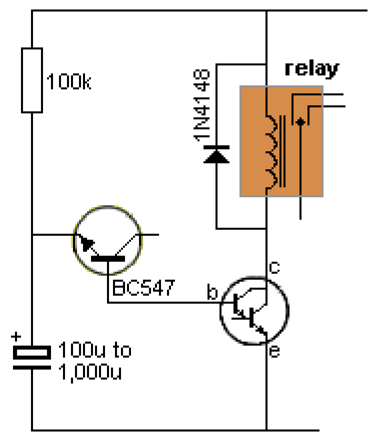
These 4 circuits are all the same. They supply power to a project for a short period of time. You can select either PNP or NPN transistors or Darlington transistors. The output voltage gradually dies and this will will produce weird effects with some projects. See circuit 4 in Time Delay Circuits (below) for a relay that remains active for a few seconds after the push button has been released.

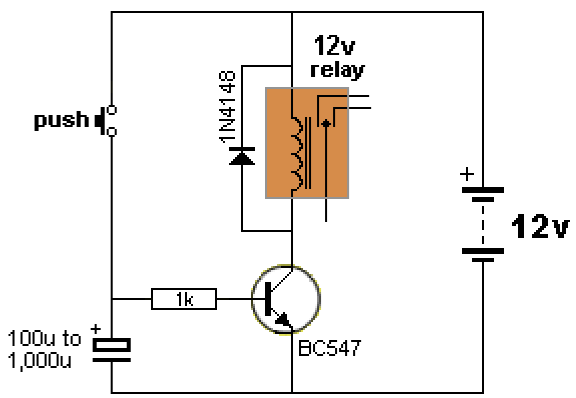


TIME DELAY CIRCUITS

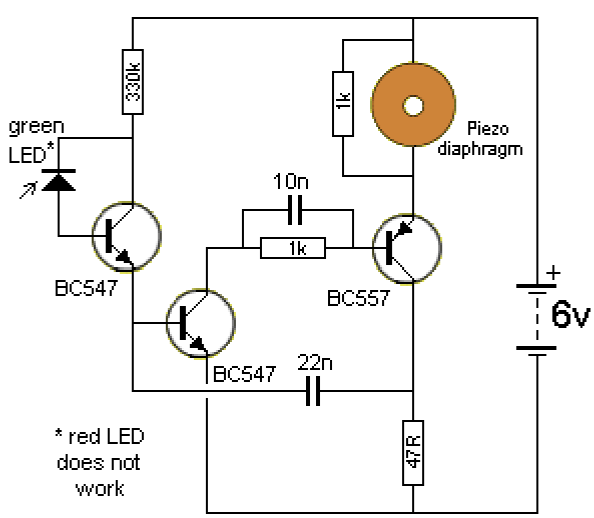
These 3 circuits are all the same. They turn on a relay after a period of time.
The aim of the circuit is to charge the electrolytic to a reasonably high voltage before the circuit turns ON. In fig 1 the voltage will be above 5v6. In fig 2 the voltage will be above 3v6. In fig 3 the voltage will be above 7v.





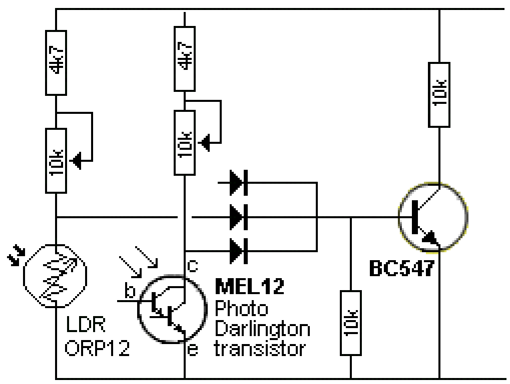


The relay in this circuit will remain active for a few seconds after the push button has been released.
The value of the 1k resistor and electrolytic can be adjusted to suit individual requirements.



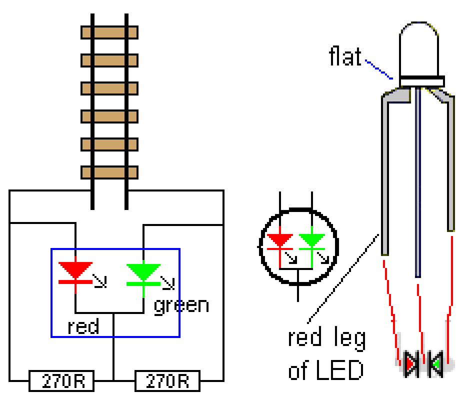
LED DETECTS LIGHT

The LED in this circuit will detect light to turn on the oscillator. Ordinary red LEDs do not work. But green LEDs, yellow LEDs and high-bright white LEDs and high-bright red LEDs work very well.
The output voltage of the LED is up to 600mV when detecting very bright illumination.
When light is detected by the LED, its resistance decreases and a very small current flows into the base of the first transistor. The transistor amplifies this current about 200 times and the resistance between collector and emitter decreases. The 330k resistor on the collector is a current limiting resistor as the middle transistor only needs a very small current for the circuit to oscillate. If the current is too high, the circuit will "freeze."
The piezo diaphragm does not contain any active components and relies on the circuit to drive it to produce the tone. A different **LED Detects Light** circuit in eBook 1:
[1 - 100 Transistor Circuits]



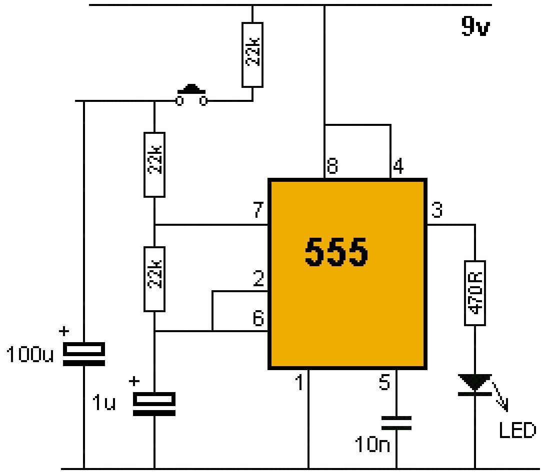
TRAIN DETECTORS

In response to a reader who wanted to parallel TRAIN DETECTORS, here is a diode OR-circuit. The resistor values on each detector will need to be adjusted (changed) according to the voltage of the supply and the types of detector being used. Any number of detectors can be added. See Talking Electronics website for train circuits and kits including Air Horn, Capacitor Discharge Unit for operating point motors without overheating the windings, Signals, Pedestrian Crossing Lights and many more.



TRACK POLARITY

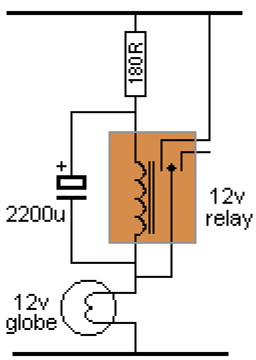
This circuit shows the polarity of a track via a 3-legged LED. The LED is called dual colour (or tri-colour) as it shows red in one direction and green in the other (orange when both LEDs are illuminated).



DECAYING FLASHER

In response to a reader who wanted a flashing LED circuit that slowed down when a button was released, the above circuit increases the flash rate to a maximum and when the button is released, the flash rate decreases to a minimum and halts.

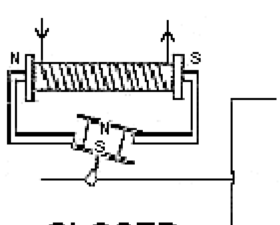
SIMPLE FLASHER



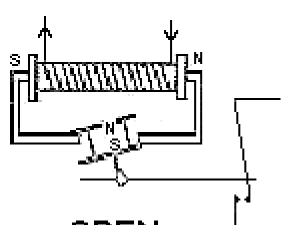
This simple circuit flashes a globe at a rate according to the value of the 180R and 2200u electrolytic.

LATCHING RELAY

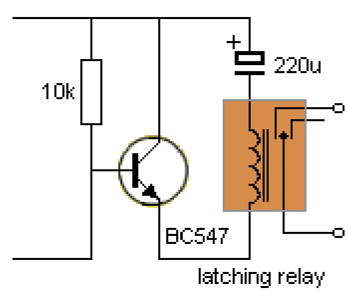
To reduce the current in battery operated equipment a relay called LATCHING RELAY can be used. This is a relay that latches itself ON when it receives a pulse in one direction and unlatches itself when it receives a pulse in the other direction.
The following diagram shows how the coil makes the magnet click in the two directions.



CLOSED



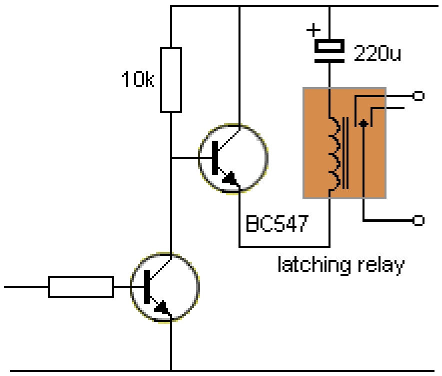
OPEN



PULSE LATCHING RELAY ON/OFF

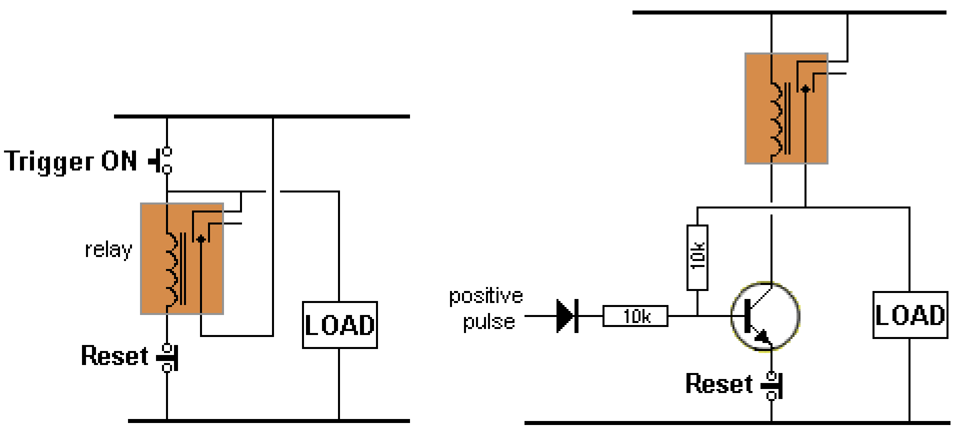
To operate this type of relay, the voltage must be reversed to unlatch it. The circuit above produces a strong pulse to latch the relay ON and the input voltage must remain HIGH. The 220u gradually charges and the current falls to a very low level. When the input voltage is removed, the circuit

produces a pulse in the opposite direction to unlatch the relay.



PULSE LATCHING RELAY ON/OFF
via a MICROCONTROLLER

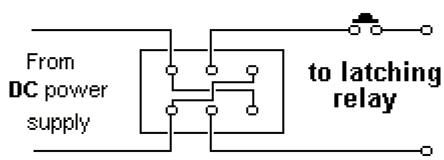
The pulse-latching circuit above can be connected to a microcontroller via the circuit at the left. The electrolytic can be increased to 1,000u to cater for relays with a low resistance.



Latching an ordinary relay

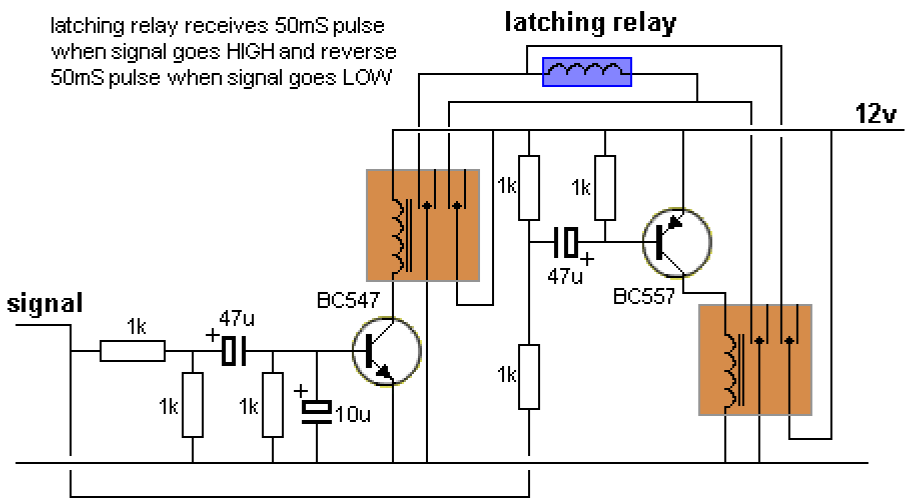
If you want to latch an ordinary relay so it remains ON after a pulse, the circuits above can be used. Power is needed all the time to keep the relay ON.

If your latching relay **latches** when it receives a 50mS pulse and **unlatches** when it receives a 50mS pulse in the opposite direction, you just need a reversing switch and a push button. You just need to flick the switch to the **latch** or **unlatch** position and push the button very quickly.



double-pole
double-throw switch

To operate a **latching relay** from a **signal,** you need the following circuit:

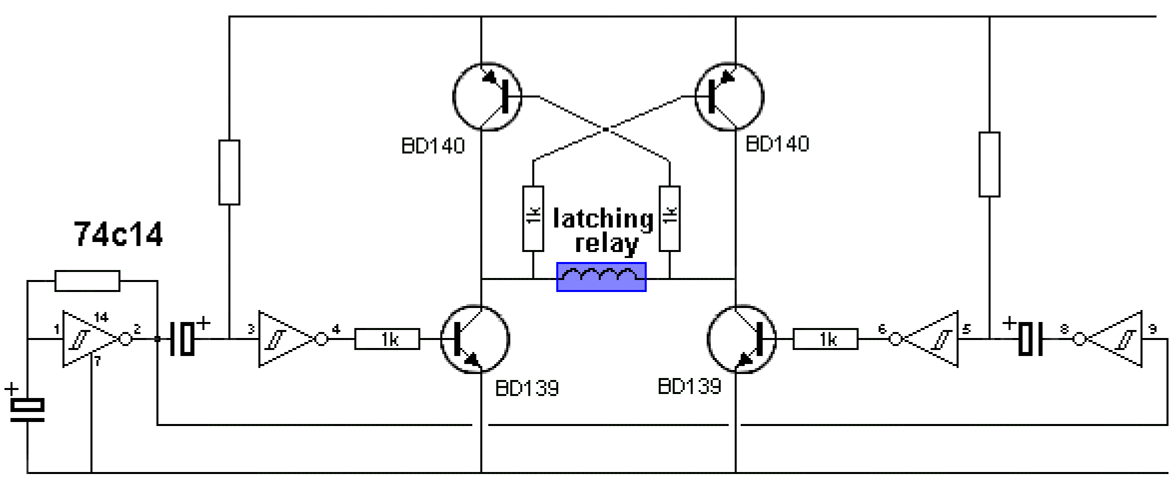


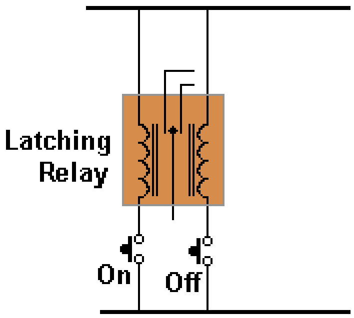
To use this circuit you have to understand some of the technical requirements.

When the signal is HIGH it has **driving power** and is classified a low impedance and it will only turn ON the BC547. If you make sure the signal is HIGH when the circuit is turned ON, you will have no problem.
But if the signal is LOW when the 12v power is applied, the **signal-line** will be effectively "floating" and the four 1k resistors in series will turn on both transistors.
The 10u is designed to delay to BC547 and it will produce the longer pulse to de-activate the relay.
You will have to adjust the value of the resistors and electrolytics to get the required pulse length and the required delay. This circuit is just a "starting-point."
This circuit has been requested by: **Stephen Derrick-Jehu** email: d-js@xtra.co.nz Contact him for the success of this circuit, with his 8 ohm 12v EHCOTEC valve B23E-1-ML-4.5vDC.

Specifications:
4.5-Volt DC minimum coil voltage
12-Volt DC maximum coil voltage
50 mS (min) pulse opens valve
50 mS pulse (min) with reverse polarity closes valve
2.5 W power consumption at 4.5vDC

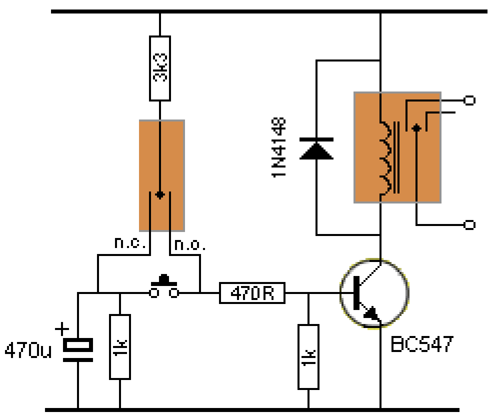
The following circuit pulses a latching relay every 30 seconds. The circuit only consumes current during the 50mS latching period.
The values for the timing components have not been provided. These can be worked out by experimentation.



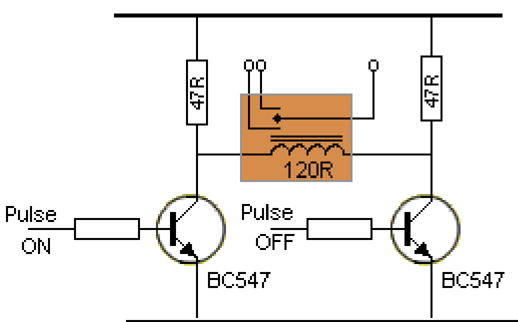


A 2-coil Latching Relay

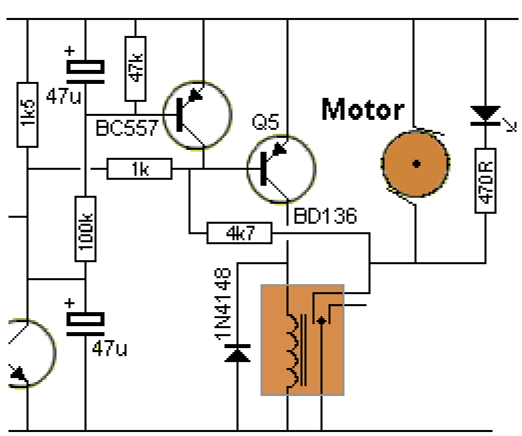
Latching Relays are expensive but a 5v Latching Relay is available from: [Excess Electronics] for $1.00 as a surplus item. It has 2 coils and requires the circuit at the left. A 5v Latching Relay can be use on 12v as it is activated for a very short period of time.



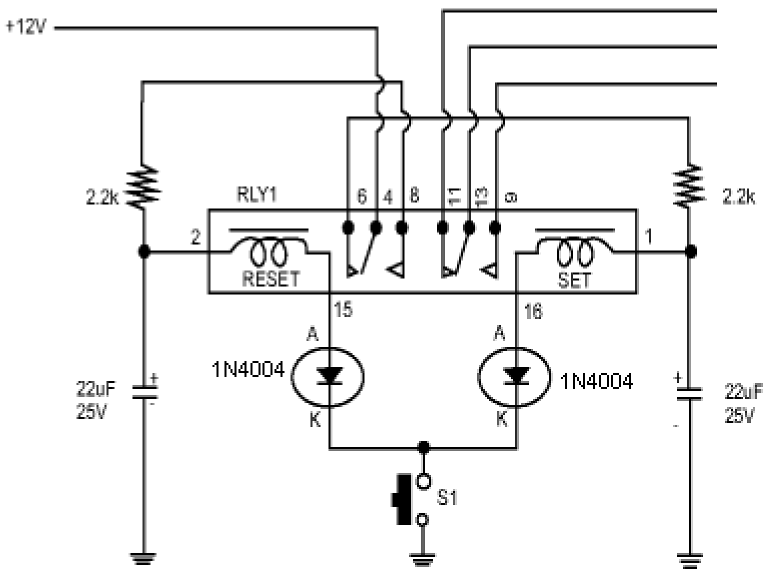
A double-pole (ordinary) relay and transistor can be connected to provide a toggle action.
The circuit comes on with the relay de-activated and the contacts connected so that the 470u charges via the 3k3. Allow the 470u to charge. By pressing the button, the BC547 will activate the relay and the contacts will change so that the 3k3 is now keeping the transistor ON. The 470u will discharge via the 1k. After a few seconds the electro will be discharged. If the press-button is now pushed for a short period of time, the transistor will turn off due to the electro being discharged.



A single-coil latching relay normally needs a reverse-voltage to unlatch but the circuit at the left provides forward and reverse voltage by using 2 transistors in a very clever H-design.
The pulse-ON and pulse-OFF can be provided from two lines of the microcontroller.



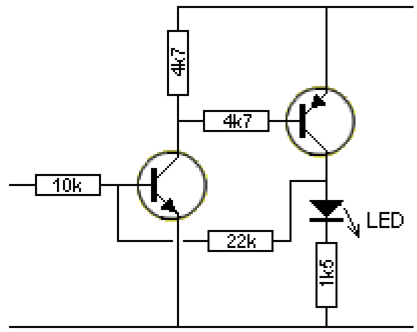
A normal relay can be activated by a short tone and de-activated by a long tone as shown via the circuit on the left. This circuit can be found in "**27MHz Links**" Page 2.

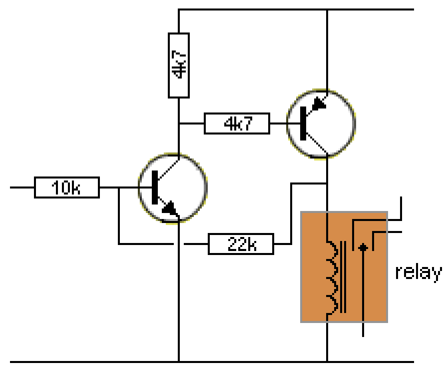


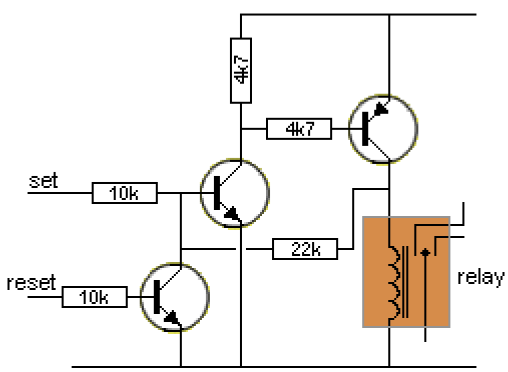
The circuit will come ON in either SET or RESET state, depending on the state of the armature in the relay.
If it comes ON in RESET state, the 2k2 on the SET coil will charge the 22u electrolytic so that when the switch is pressed, the 22u will activate the SET coil and change the state of the relay. The opposite 22u will not get charged and when the switch is pressed after a few seconds, relay will change state.
The relay is SY4060 from Jarcar Electronics.

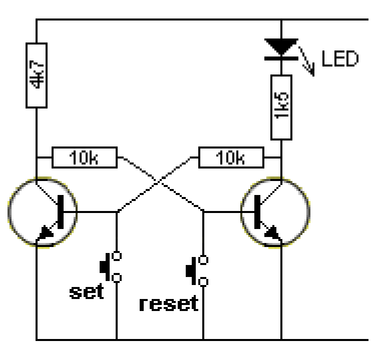
LATCH - Electronic Latch - Latch a Signal

When the circuit sees a voltage about 1v or higher, the circuit latches **ON** and illuminates the LED or relay. The third circuit provides SET and RESET. The fourth circuit provides SET and RESET via a bi-stable arrangement.



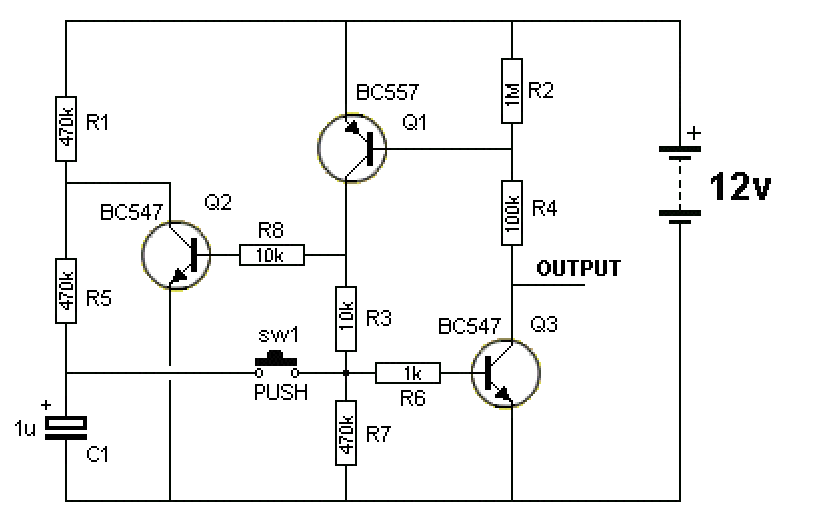






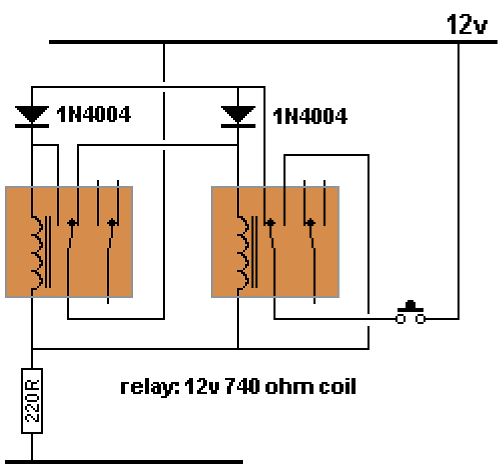
LATCHING A PUSH BUTTON - also called: PUSH-ON PUSH-OFF

When the circuit is turned on, capacitor C1 charges via the two 470k resistors. When the switch is pressed, the voltage on C1 is passed to Q3 to turn it on. This turns on Q1 and the voltage developed across R7 will keep Q1 turned on when the button is released.
Q2 is also turned on during this time and it discharges the capacitor. When the switch is pressed again, the capacitor is in a discharged state and this zero voltage will be passed to Q3 turn it off. This turns off Q1 and Q2 and the capacitor begins to charge again to repeat the cycle.



TOGGLE A PUSH BUTTON - using 2 relays

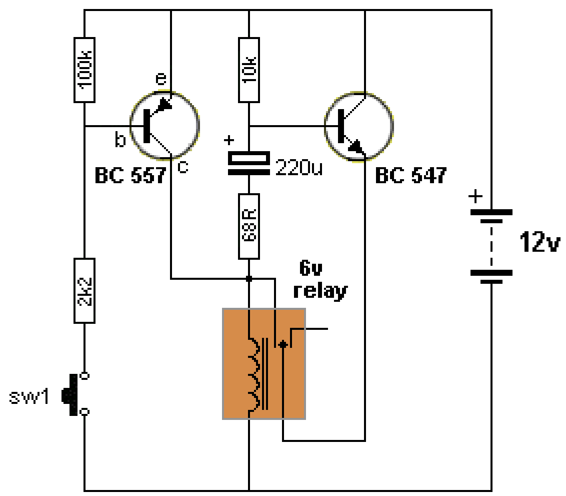
The circuit is shown with the second relay "active."
Half of each relay is used for the toggle function and the other half can be connected to an application.
The first relay (which is off), applies voltage from its contacts and latches the second relay "on". The condition changes when the switch is pressed. Voltage is applied to the first relay, latching it "on."
Releasing the switch turns the second relay "off".
When the switch is pressed again, 12v is applied to both ends of the first relay and it turns off. The second relay turns "on" when the switch is released. There is slight lag in the action, depending on how long the switch is pressed.



TOGGLE A RELAY

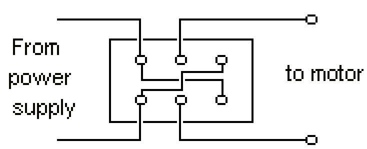
This circuit will activate a relay when the switch is pressed and released quickly and turn the relay off when the switch is pressed for about 1 second then released.
The circuit relies on a few component values to operate correctly and they may need to be adjusted to get the circuit to operate exactly as required.
When the switch is pressed, The BC557 turns ON and supplies nearly rail voltage to the relay.
This closes the contacts and the BC547 is capable of delivering a current to the relay.
The transistor acts just like a resistor with a resistance equal to 1/250 the value of the base resistor.
This is 40 ohms. If the relay has a coil resistance of 250 ohms, it will see a voltage of about 10v for a 12v supply.
When the switch is released, the BC547 keeps the relay energised.
During this activation, the 220u electrolytic helps in activating the relay.
Here's how:
Initially the 220u is charged (quite slowly) via the 10k resistor 68 ohm resistor and the coil of the relay.

It is now fully charged and when the switch is pressed, the negative end of the electrolytic is raised via the collector of the BC557. The positive end rises too and this action raises the emitter and when the relay contacts close, the relay is delivered current fro both the BC557 and and BC547. When the sw is released, the BC547 takes over and the discharging of the 220u into the base, holds the relay closed. As the 220u gradually discharges, the ability of the BC547 to deliver current reduces slightly and the 10k base resistor takes over and turns the transistor into a 40R resistor.
Finally the 220u has a very small voltage across it.
When the switch is pressed again, the BC547 acts as a resistor with a resistance less than 40 ohms and it is able to deliver a voltage slightly higher than that provided by the BC547.
This slightly higher voltage is passed to the negative lead of the 220u and the positive lead actually rises about rail voltage and the electro gets discharged via the 10k resistor.
When the switch is released, the electro has less than 0.6v across it and the BC547 transistor is not able to deliver current to the relay. The relay is de-activated.



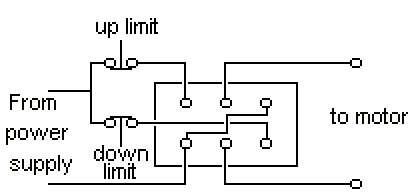
REVERSING A MOTOR-1

There are a number of ways to reverse a motor. The following diagrams show how to connect a double-pole double throw relay or switch and a set of 4 push buttons. The two buttons must be pushed at the same time or two double pole push-switches can be used.
See H-Bridge below for more ways to reverse a motor.

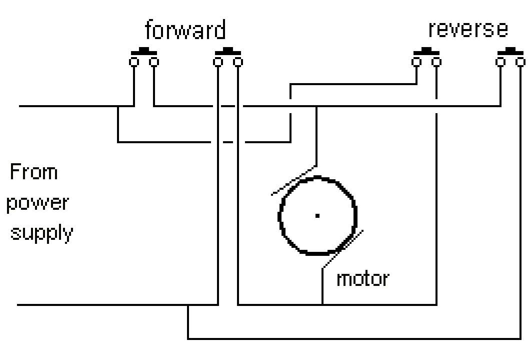


double-pole double-throw relay

Adding limit switches:



double-pole double-throw relay

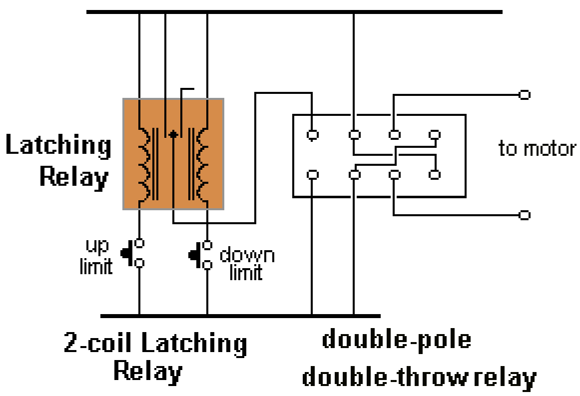


The way the dpdt relay circuit (above) works is this:
The relay is powered by say 12v, via a MAIN SWITCH. When the relay is activated, the motor travels in the forward direction and hits the "up limit" switch. The motor stops. When the MAIN SWITCH is turned off, the relay is de-activated and reverses the motor until it reaches th e "down-limit" switch and stops. The MAIN SWITCH must be used to send the motor to the "up limit" switch.

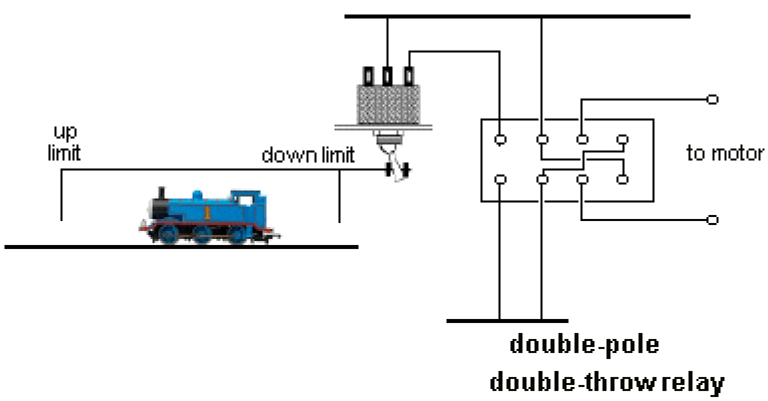
REVERSING A MOTOR-2

AUTOMATIC FORWARD-REVERSE

The following circuit allows a motor (such as a train) to travel in the forward direction until it hits the "up limit" switch. This sends a pulse to the latching relay to reverse the motor (and ends the short pulse). The train travels to the "down limit" switch and reverses.

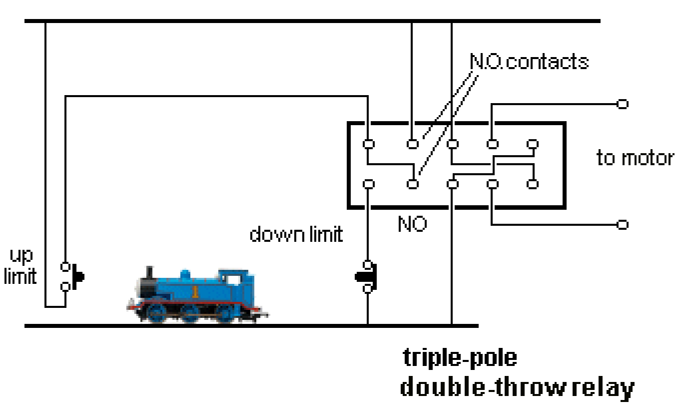


If the motor can be used to click a switch or move a slide switch, the following circuit can be used:



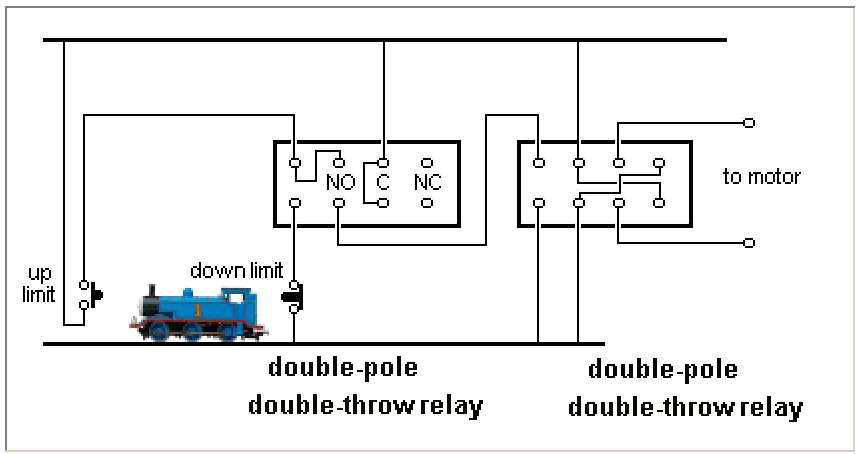
REVERSING A MOTOR-3

If the train cannot physically click the slide switch in both directions, via a linkage, the following circuit should be used:



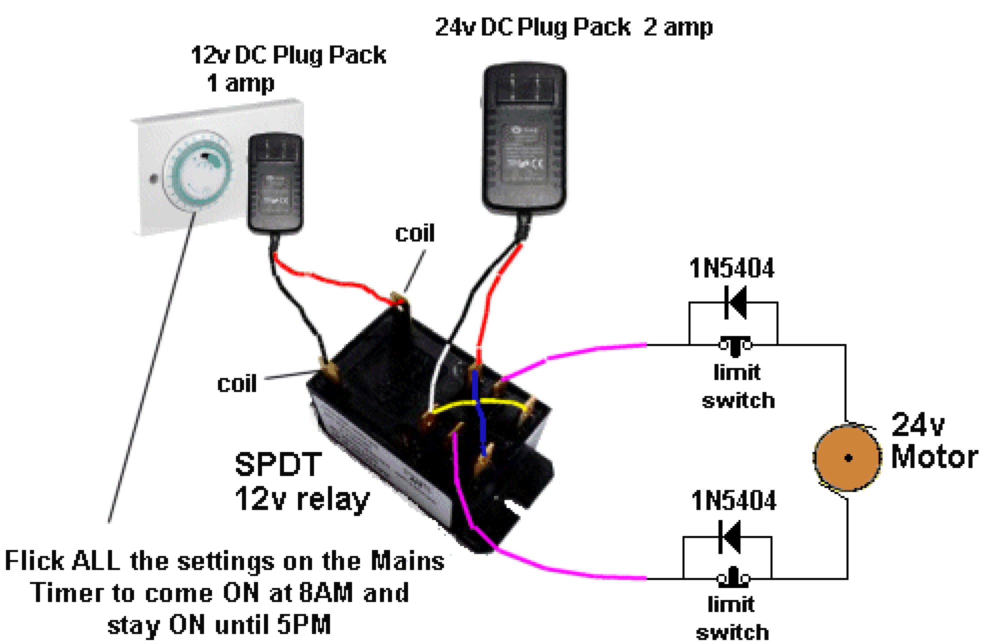
When power is applied, the relay is not energised and the train **must** travel towards the "up limit." The switch is pressed and the relay is energised. The Normally Open contacts of the relay will close and this will keep the relay energised and reverse the train. When the down limit is pressed, the relay is de-energised.

If you cannot get a triple-pole change-over relay, use the following circuit:



AUTOMATIC BLINDS

This circuit can be used for anything that needs to be automatically opened or closed via a MAINS TIMER.
Normally the Timer turns on a lamp. Our circuit uses a Wall Wart in the Mains Timer socket and the 12v "Plug Pack" activates a 12v relay.

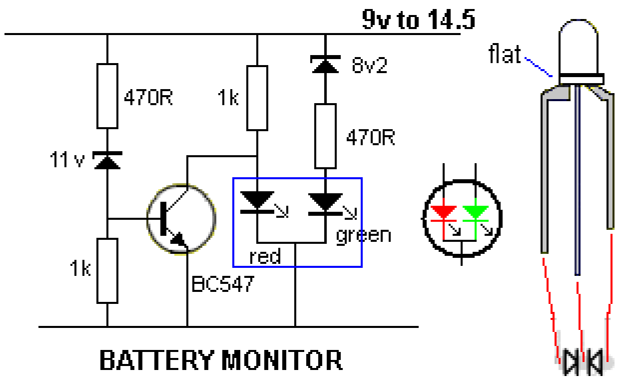


The relay sends (say) positive out the top lead and when the top limit switch is opened by the motor reaching the end of its travel, it stops. The top 1N5404 prevents current passing to the motor. At 5PM the Mains timer turns the relay OFF and it sends negative out the top lead. The top 3 amp diode allows the motor to reverse and then the limit switch closes. When it reaches the lower limit switch, the switch opens and the lower diode prevents current flowing to the motor.

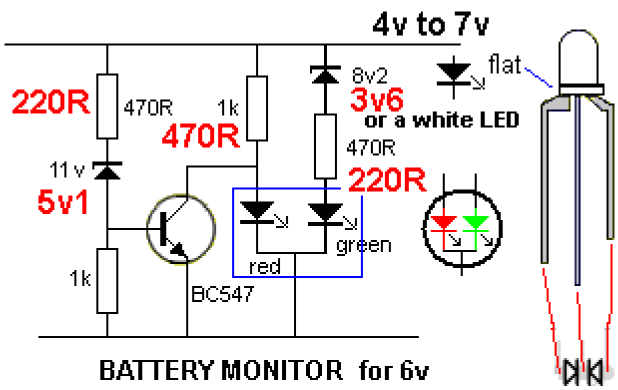
BATTERY MONITOR MkI

A very simple battery monitor can be made with a dual-colour LED and a few surrounding components. The LED produces orange when the red and green LEDs are illuminated.
The following circuit turns on the red LED below 10.5v

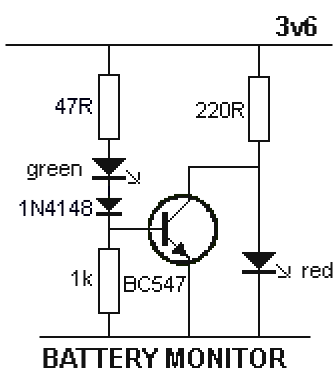
The orange LED illuminates between 10.5v and 11.6v.
The green LED illuminates above 11.6v

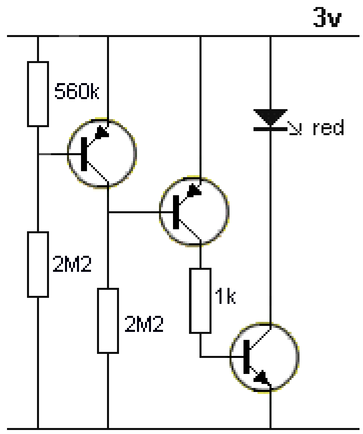


BATTERY MONITOR for 6v:



The following circuit monitors a single Li-ION cell. The green LED illuminates when the voltage is above 3.5v and the goes out when the voltage falls below 3.4v. The red LED then illuminates.



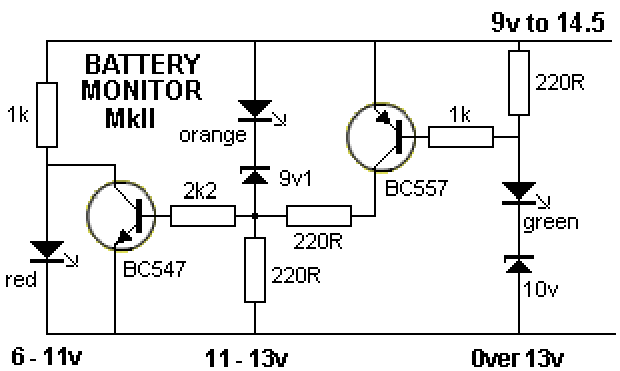


VERY LOW CURRENT
BATTERY MONITOR

Adjust the 560k for the voltage at which the LED turns ON. No current-limiting resistor is needed as the transistor only allows a few milliamp collector curent.

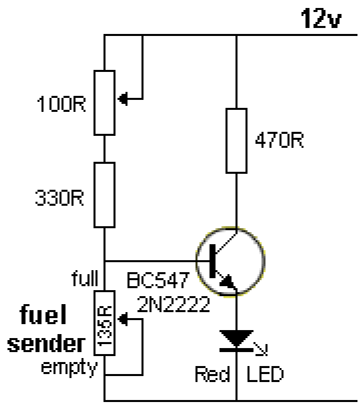
BATTERY MONITOR MkII

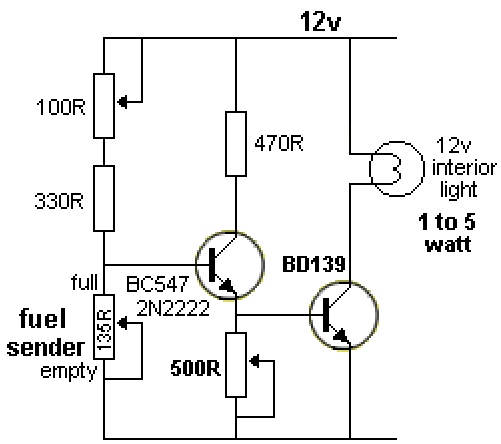
This battery monitor circuit uses 3 separate LEDs.
The red LED turns on from 6v to below 11v.
It turns off above 11v and
The orange LED illuminates between 11v and 13v.
It turns off above 13v and
The green LED illuminates above 13v



LOW FUEL INDICATOR

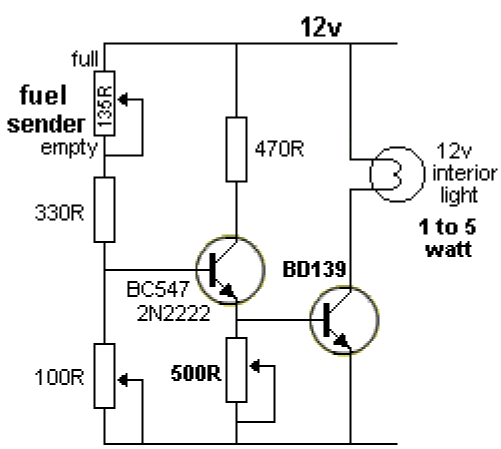
The first circuit has been designed from a request by a reader. He wanted a low fuel indicator for his motorbike. The LED illuminates when the fuel gauge is 90 ohms. The tank is empty at 135 ohms and full at zero ohms. To adapt the circuit for an 80 ohm fuel sender, simply reduce the 330R to 150R. (The first thing you have to do is measure the resistance of the sender when the tank is amply.)
The second circuit uses a power transistor to drive a lamp.

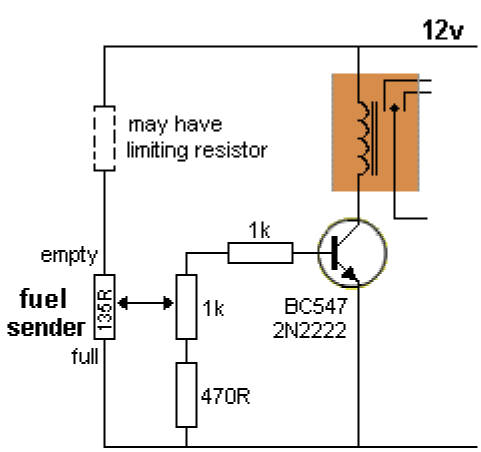




HIGH FUEL INDICATOR

This circuit illuminates a lamp when the fuel has nearly filled the tank. It could also activate an alarm:

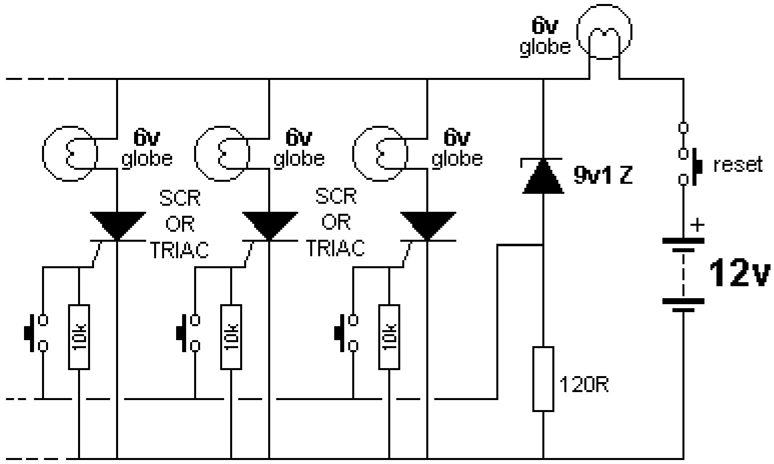




Relay DROPS OUT when the output voltage of the fuel sender is about 0.8v

QUIZ TIMER

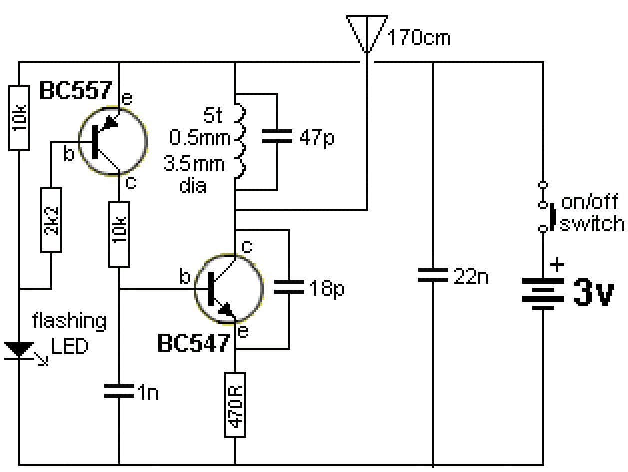
This circuit can be used to indicate: "fastest finger first." It has a globe for each contestant and one for the Quiz Master.



When a button is pressed the corresponding globe is illuminated. The Quiz Master globe is also illuminated and the cathode of the 9v1 zener sees approx mid-rail voltage. The zener comes out of conduction and no voltage appears across the 120R resistor. No other globes can be lit until the circuit is reset.

TRACKING TRANSMITTER

This circuit can be used to track lots of items.

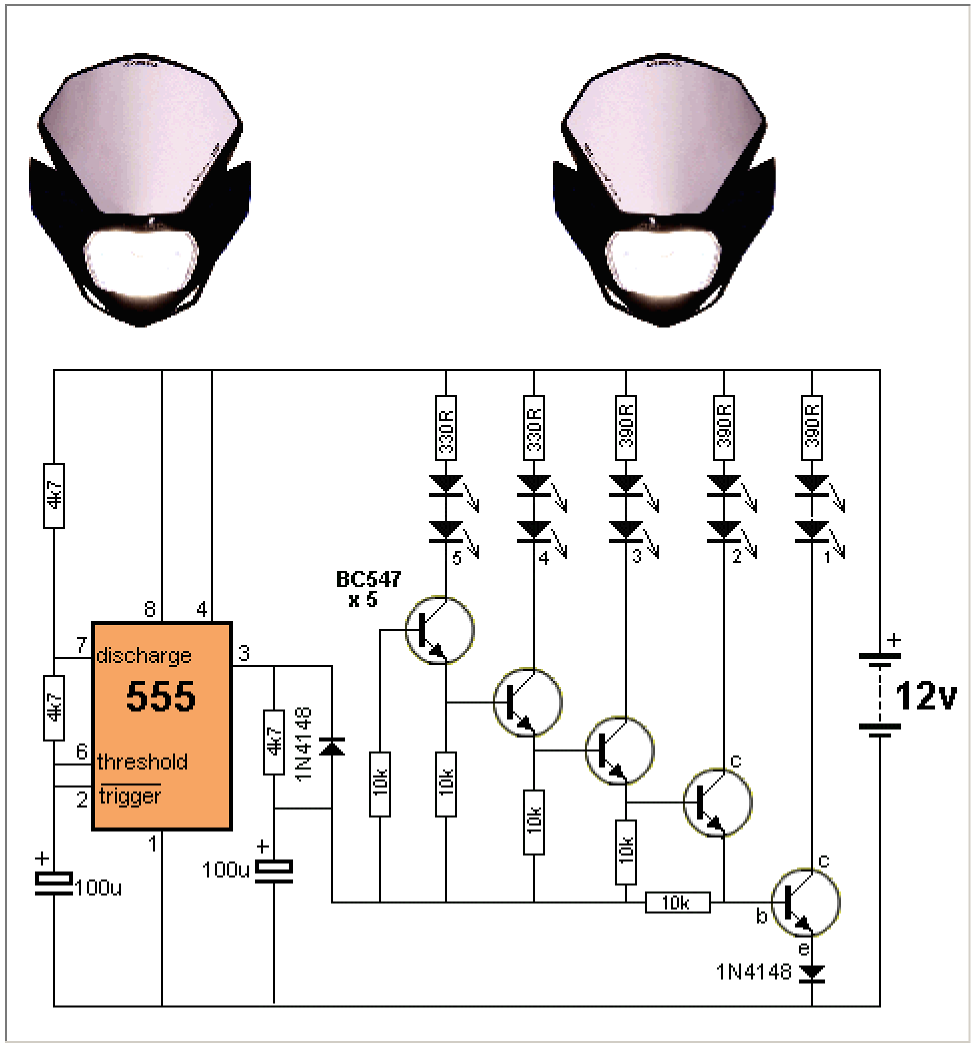


TRACKING TRANSMITTER MKI

It has a range of 200 - 400 metres depending on the terrain and the flashing LED turns the circuit ON when it flashes. The circuit consumes 5mA when producing a carrier (silence) and less than 1mA when off (background snow is detected).

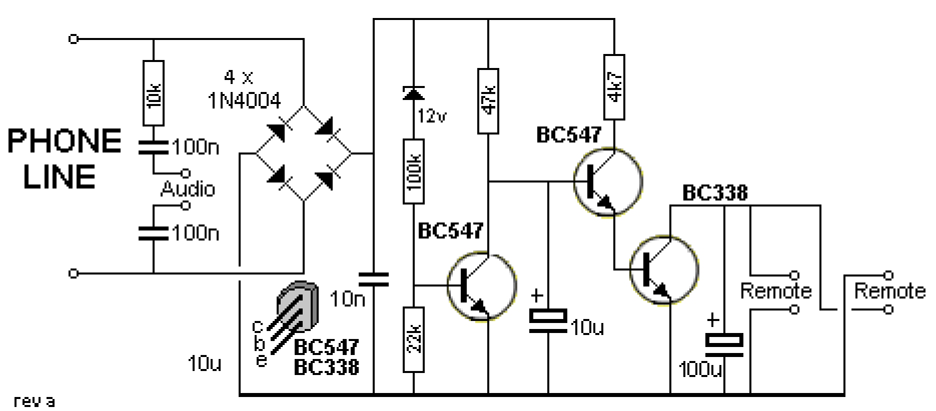
BIKE TURNING SIGNAL

This circuit can be used to indicate left and right turn on a motor-bike. Two identical circuits will be needed, one for left and one for right.



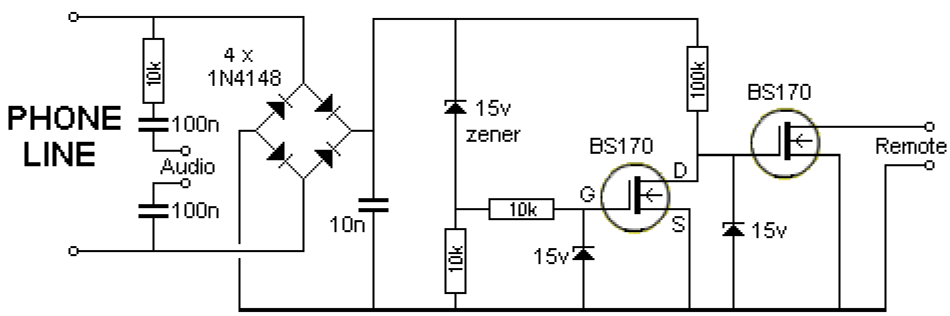
PHONE TAPE-3

This circuit can be used to turn on a tape recorder when the phone line voltage is less than 15v. This is the approximate voltage when the handset is picked up. See Phone Tape-1 and Phone Tape-2 in **200 Transistor Circuits eBook (circuits 1 - 100).** When the line voltage is above 25v, the BC547 is turned on and this robs the base of the second BC547 of the 1.2v it needs to turn on. When the line voltage drops, the first BC547 turns off and the 10u charges via the 47k and gradually the second BC547 is turned on. This action turns on the BC338 and the resistance between its collector-emitter leads reduces. Two leads are taken from the BC338 to the "rem" (remote) socket on a tape recorder. When the lead is plugged into a tape recorder, the motor will stop. If the motor does not stop, a second remote lead has been included with the wires connected the opposite way. This lead will work. The audio for the tape recorder is also shown on the diagram. This circuit has the advantage that it does not need a battery. It will work on a 30v phone line as well as a 50v phone line.



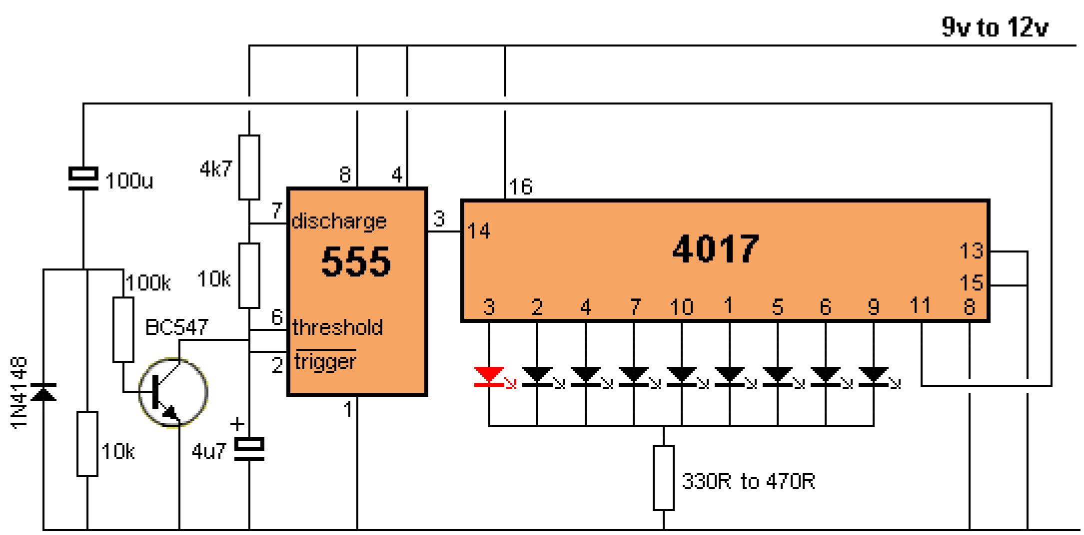
PHONE TAPE-4

This circuit is identical in operation to the circuit above but uses FET's (Field Effect Transistors.
15v zeners are used to prevent the gate of each FET from rising above 15v.
A FET has two advantages over a transistor in this type of circuit.
1. It takes very little current into the gate to turn it on. This means the gate resistor can be very high.
2. The voltage developed across the output of a FET is very low when the FET is turned on. This means the motor in the tape recorder will operate at full strength.
This circuit has not been tested and the 10k resistor (in series with the first 15v zener) creates a low impedance and the circuit may not work on some phone systems.



SEQUENCER

This circuit has been requested by a reader. He wanted to have a display on his jacket that ran 9 LEDs then stopped for 3 seconds.
The animated circuit shows this sequence:

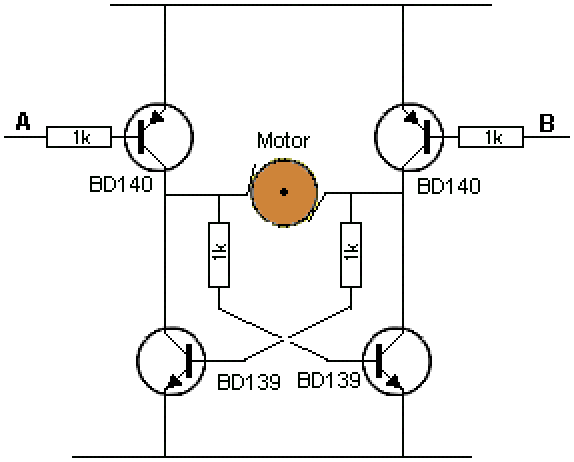


SEQUENCER WITH 3 SECOND INTERVAL

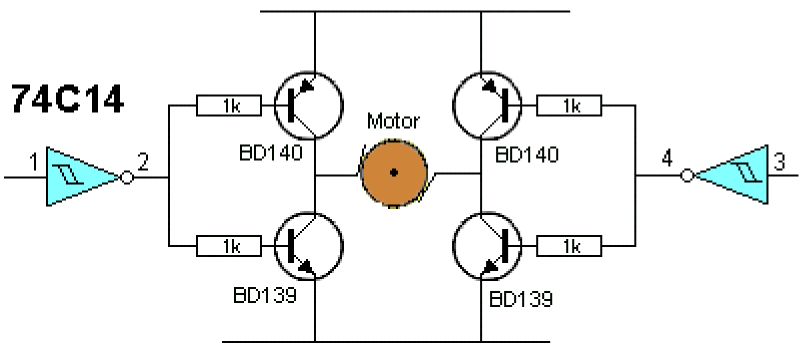
Note the delay produced by the 100u and 10k produces 3 seconds by the transistor inhibiting the 555 (taking pin 6 LOW). Learn more about the 555 - see the article: **"The 555"** on Talking Electronics website by clicking the title on the left index. See the article on CD 4017. See **"Chip Data eBook"** on TE website in the left index.

H-BRIDGE

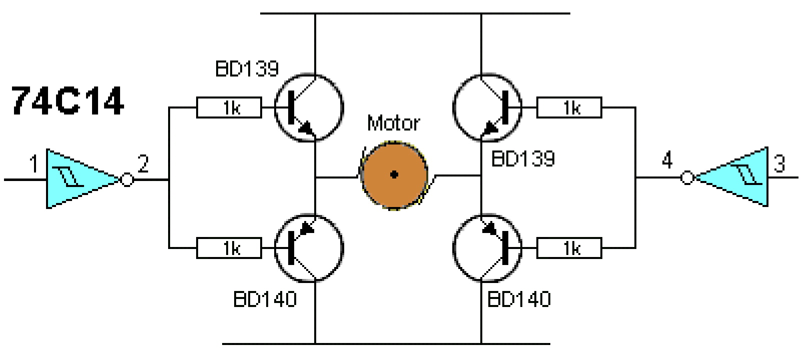
These circuits reverse a motor via two input lines. Both inputs must not be LOW with the first H-bridge circuit. If both inputs go LOW at the same time, the transistors will "short-out" the supply. This means you need to control the timing of the inputs. In addition, the current capability of some H-bridges is limited by the transistor types.



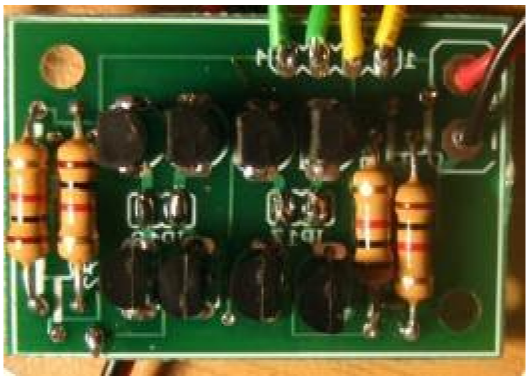
A and B must NEVER both be low



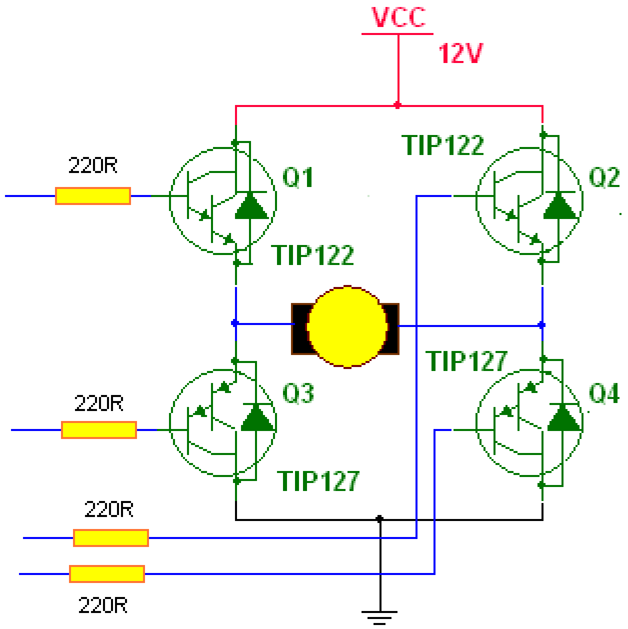
When A and B are equal, motor does not run



The driver transistors are in "emitter follower" mode in this circuit.



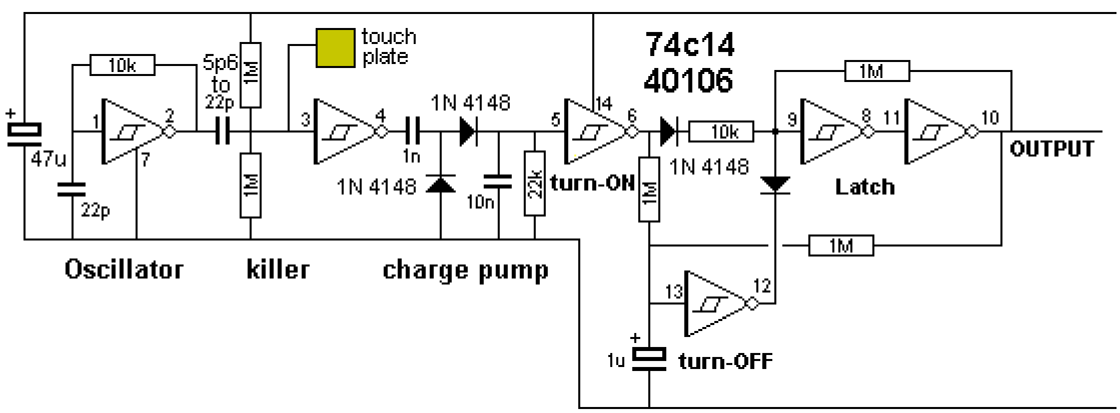
Two H-Bridges on a PC board



H-Bridge using Darlington transistors

TOUCH-ON TOUCH-OFF SWITCH

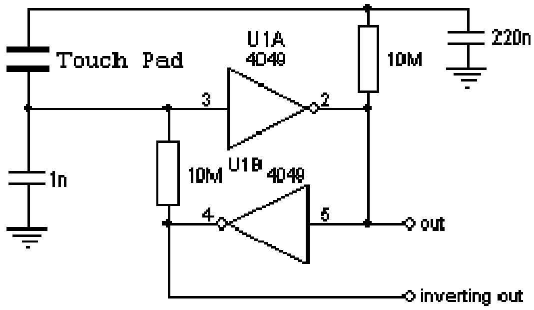
This circuit will create a HIGH on the output when the Touch Plate is touched briefly and produce a low when the plate is touched again for a slightly longer period of time. Most touch switches rely on 50Hz mains hum and do not work when the hum is not present. This circuit does not rely on "hum."



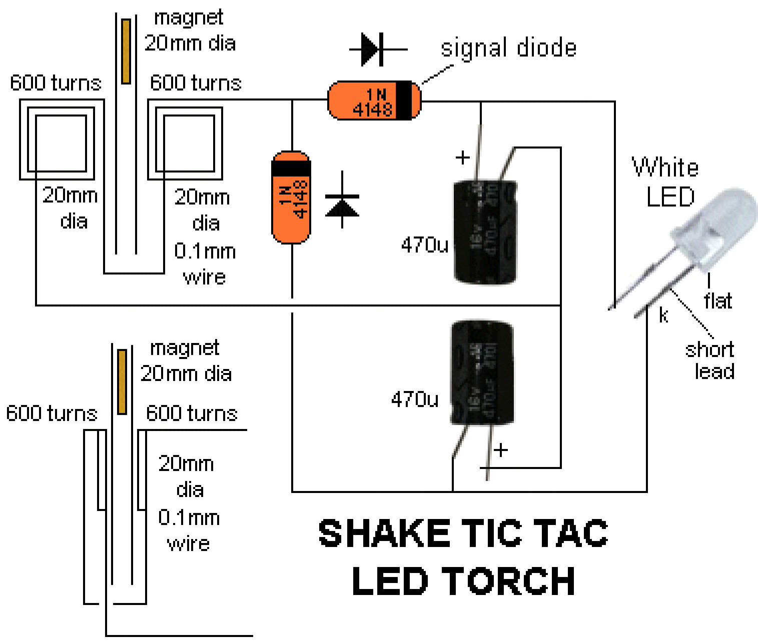
TOUCH-ON TOUCH-OFF SWITCH

SIMPLE TOUCH-ON TOUCH-OFF SWITCH

This circuit will create a HIGH on the output when the Touch Plate is touched briefly and produce a low when the plate is touched again.



SHAKE TIC TAC LED TORCH

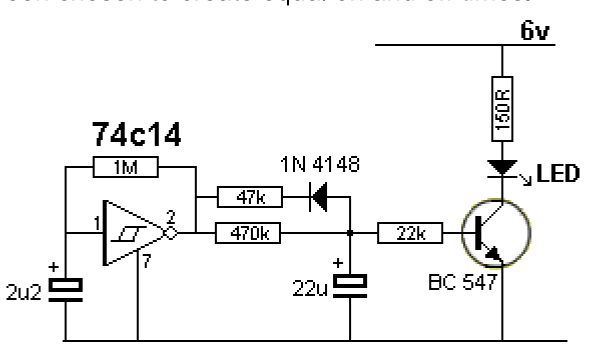


In the diagram, it looks like the coils sit on the "table" while the magnet has its edge on the table. This is just a diagram to show how the parts are connected. The coils actually sit flat against the slide (against the side of the magnet) as shown in the diagram: The output voltage depends on how quickly the magnet passes from one end of the slide to the other. That's why a rapid shaking produces a higher voltage. You must get the end of the magnet to fully pass though the coil so the voltage will be a maximum. That's why the slide extends past the coils at the top and bottom of the diagram.

The circuit consists of two 600-turn coils in series, driving a voltage doubler. Each coil produces a positive and negative pulse, each time the magnet passes from one end of the slide to the other.
The positive pulse charges the top electrolytic via the top diode and the negative pulse charges the lower electrolytic, via the lower diode.
The voltage across each electrolytic is combined to produce a voltage for the white LED. When the combined voltage is greater than 3.2v, the LED illuminates. The electrolytics help to keep the LED illuminated while the magnet starts to make another pass.

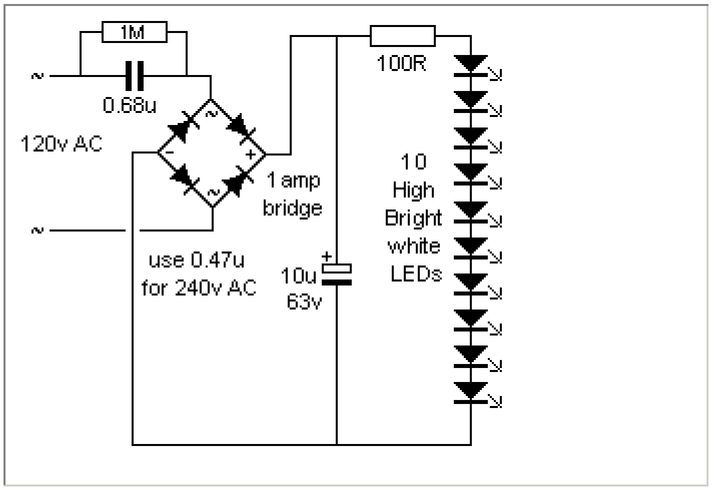
FADING LED

The circuit fades the LED ON and OFF at an equal rate. The 470k charging and 47k discharging resistors have been chosen to create equal on and off times.



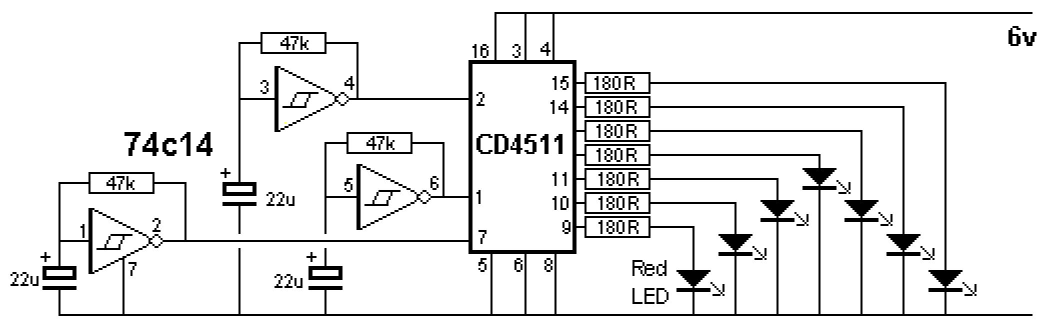
MAINS NIGHT LIGHT

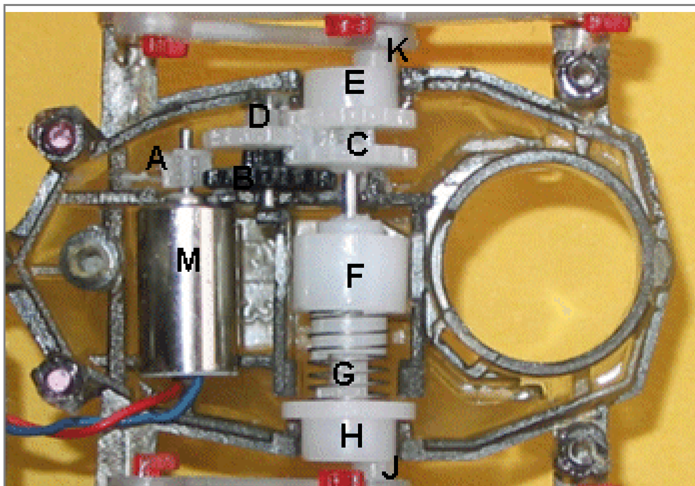
The circuit illuminates a column of 10 white LEDs. The 10u prevents flicker and the 100R also reduces flicker.



RANDOM BLINKING LEDS

This circuit blinks a set of LEDs in a random pattern according to the slight differences in the three Schmitt Trigger oscillators. The CD4511 is BCD to 7-segment Driver





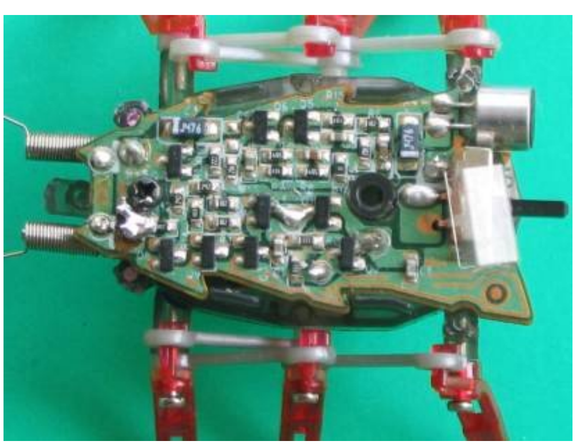
HEX BUG

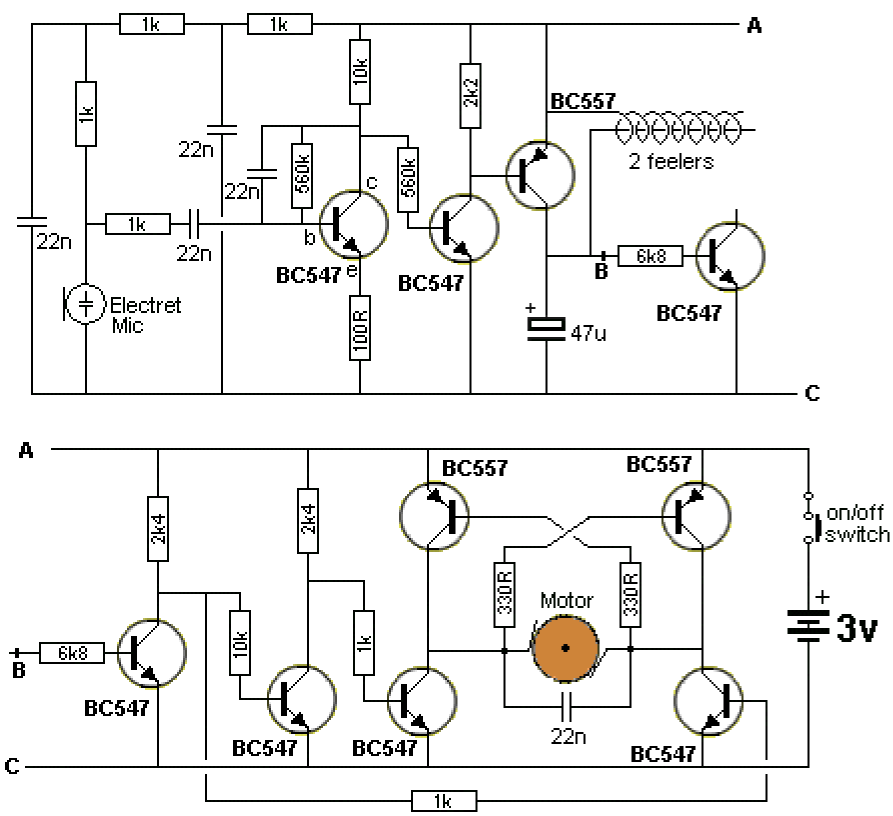
This is the circuit from a HEX BUG. It is a surface-mount bug with 6 legs. The pager motor is driven by an H-Bridge and "walks" to a wall where a feeler (consisting of a spring with a stiff wire down the middle) causes the motor to reverse.

In the forward direction, both sets of legs are driven by the compound gearbox but when the motor is reversed, the left legs do not operate as they are connected by a clutch consisting of a spring-loaded inclined plane that does not operate in reverse.

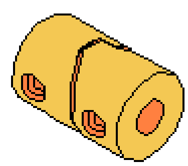
This causes the bug to turn around slightly.

The circuit also responds to a loud clap. The photo shows the 9 transistors and accompanying components:





HEX BUG CIRCUIT



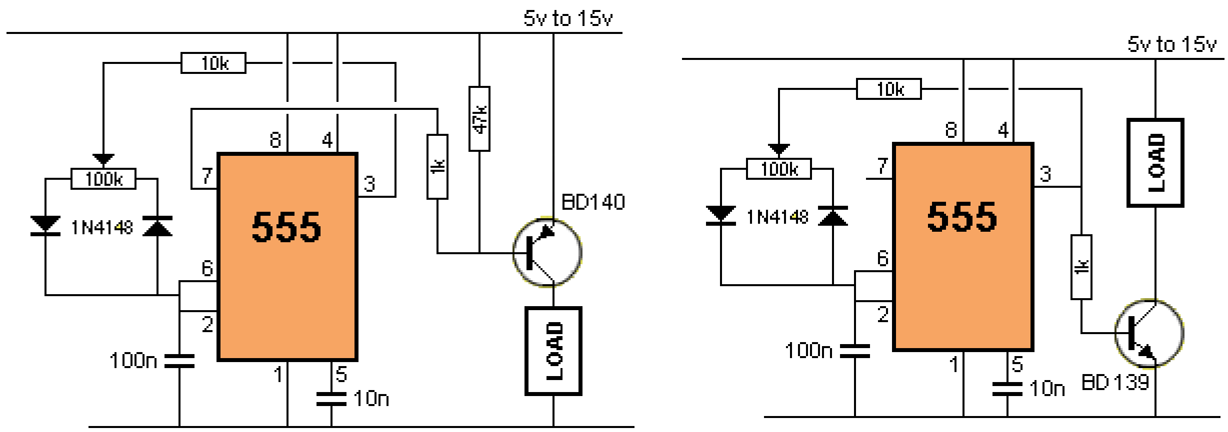
Inclined Dog Clutch

HEX BUG GEARBOX

Hex Bug gearbox consists of a compound gearbox with output "K" (eccentric pin) driving the legs. You will need to see the project to understand how the legs operate.
When the motor is reversed, the clutch "F" is a housing that is spring-loaded to "H" and drives "H via a square shaft "G". Gearwheel "C" is an idler and the centre of "F" is connected to "E" via the shaft. When "E" reverses, the centre of "F" consists of a driving inclined plane and pushes "F" towards "H" in a clicking motion. Thus only the right legs reverse and the bug makes a turn. When "E" is driven in the normal direction, the centre of "F" drives the outer casing "F" via an action called an "Inclined Dog Clutch" and "F" drives "G" via a square shaft and "G" drives "H" and "J" is an eccentric pin to drive the legs.
The drawing of an Inclined Dog Clutch shows how the clutch drives in only one direction. In the reverse direction it rides up on the ramp and "clicks" once per revolution. The spring "G" in the photo keeps the two halves together.
See **Ladybug Robot** in "100 IC Circuits" for an op-amp version of this project.

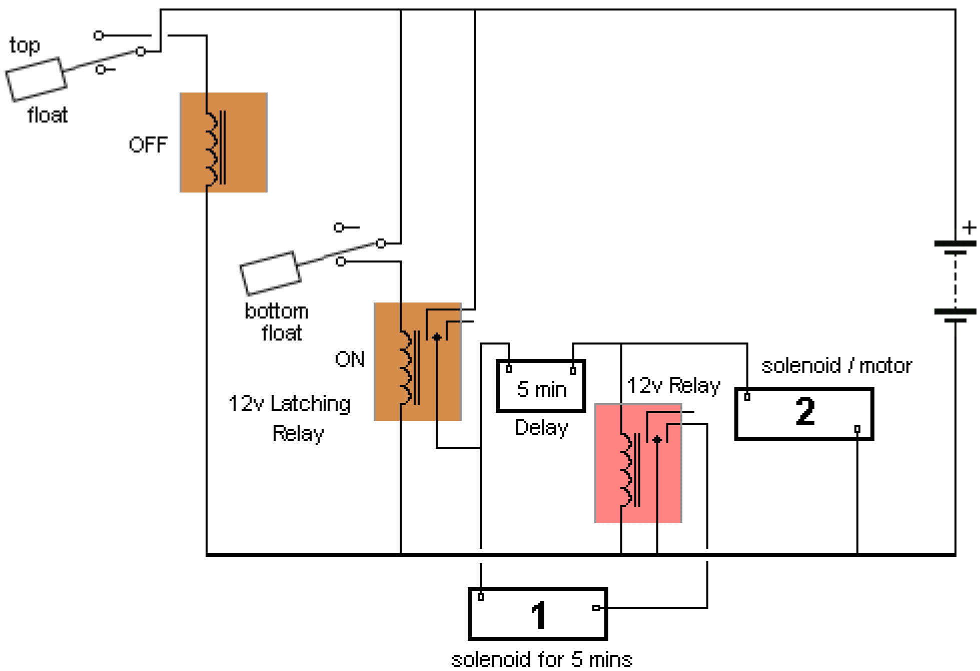
PWM CONTROLLER

This 555 based PWM controller features almost 0% to 100% pulse width regulation using the 100k variable resistor, while keeping the oscillator frequency relatively stable. The frequency is dependent on the 100k pot and 100n to give a frequency range from about 170Hz to 200Hz.



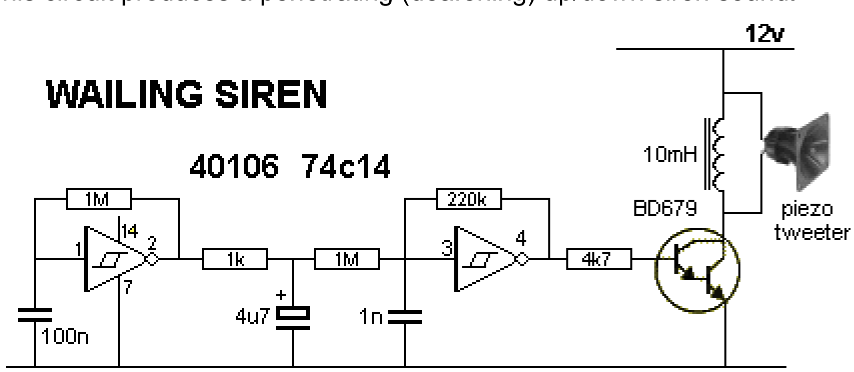
LIMIT SWITCHES

This circuit detects when the water level is low and activates solenoid (or pump) 1 for 5 minutes (adjustable) to allow dirty water to be diverted, before filling the tank via solenoid 2.



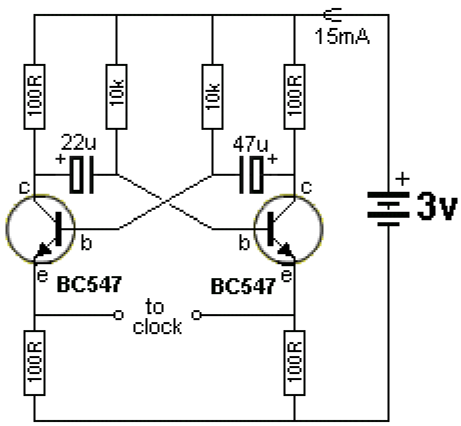
WAILING SIREN

This circuit produces a penetrating (deafening) up/down siren sound.

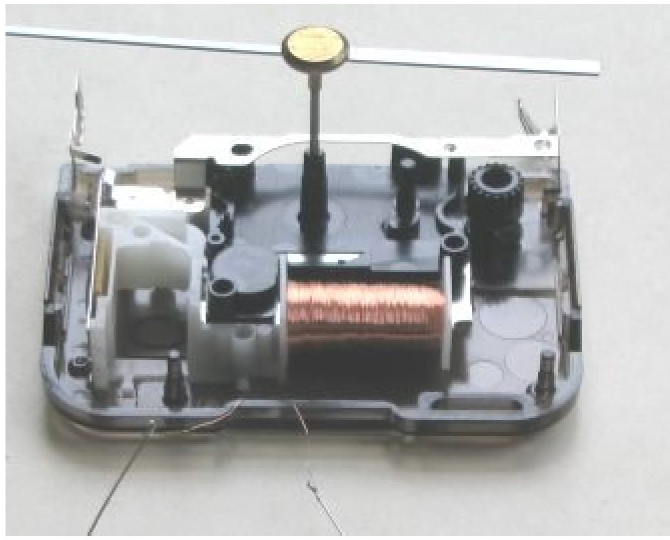


MODEL RAILWAY TIME

Here is a simpler circuit than MAKE TIME FLY from our first book of 100 transistor circuits.
For those who enjoy model railways, the ultimate is to have a fast clock to match the scale of the layout. This circuit will appear to "make time fly" by revolving the seconds hand once every 6 seconds. The timing can be adjusted by the electrolytics in the circuit. The electronics in the clock is disconnected from the coil and the circuit drives the coil directly. The circuit takes a lot more current than the original clock (1,000 times more) but this is the only way to do the job without a sophisticated chip.

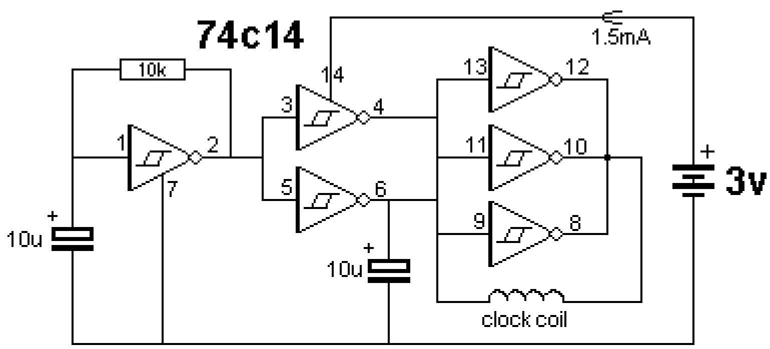


Model Railway Time Circuit



Connecting the circuit to the clock coil

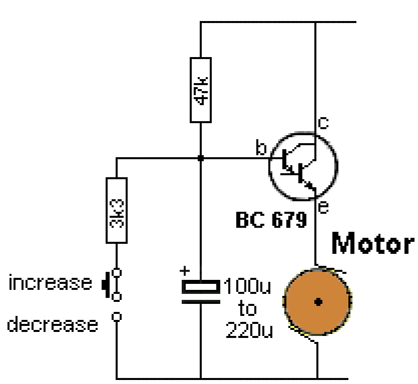
For those who want the circuit to take less current, here is a version using a Hex Schmitt Trigger chip:



Model Railway Time Circuit using a 74c14 Hex Schmitt Chip

SLOW START-STOP

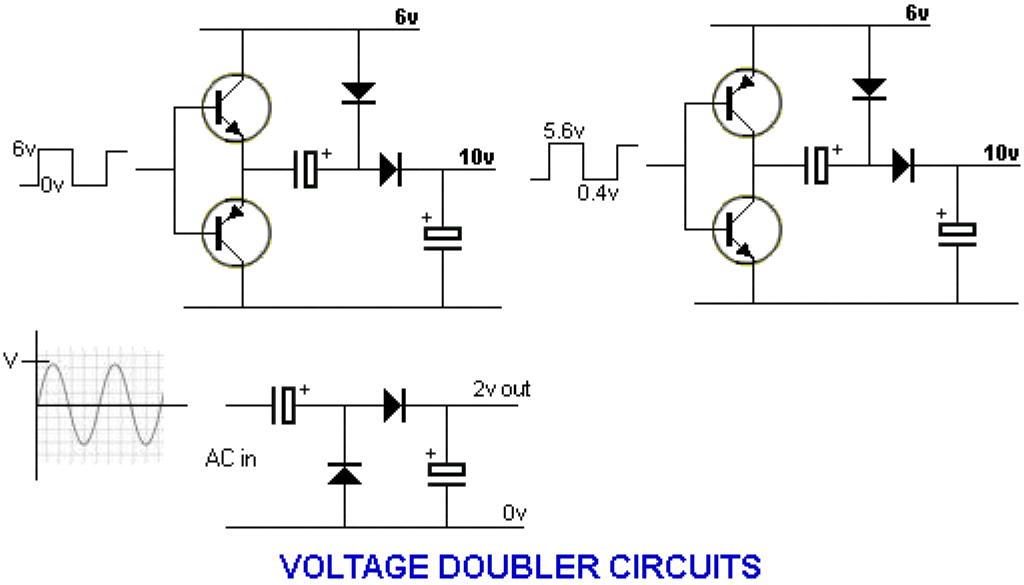
To make a motor start slowly and slow down slowly, this circuit can be used. The slide switch controls the action. The Darlington transistor will need a heatsink if the motor is loaded.



Slow Start-Stop Circuit

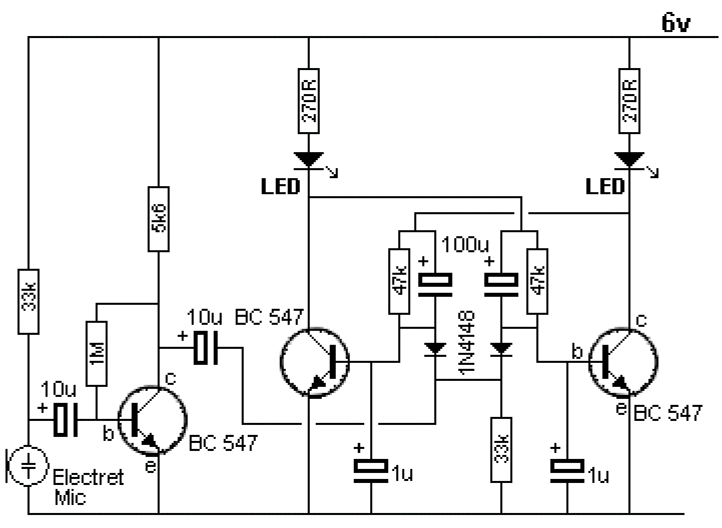
VOLTAGE MULTIPLIERS

The first circuit takes a square wave (any amplitude) and doubles it - minus about 2v losses in the diodes and base-emitter of the transistors.
The second circuit must rise to at least 5.6v and fall to nearly 0.4v for the circuit to work. Also the rise and fall times must be very fast to prevent both transistors coming on at the same time and short-circuiting.
The third circuit doubles an AC voltage. The AC voltage rises "V" volts above the 0v rail and "V" volts below the 0v rail.



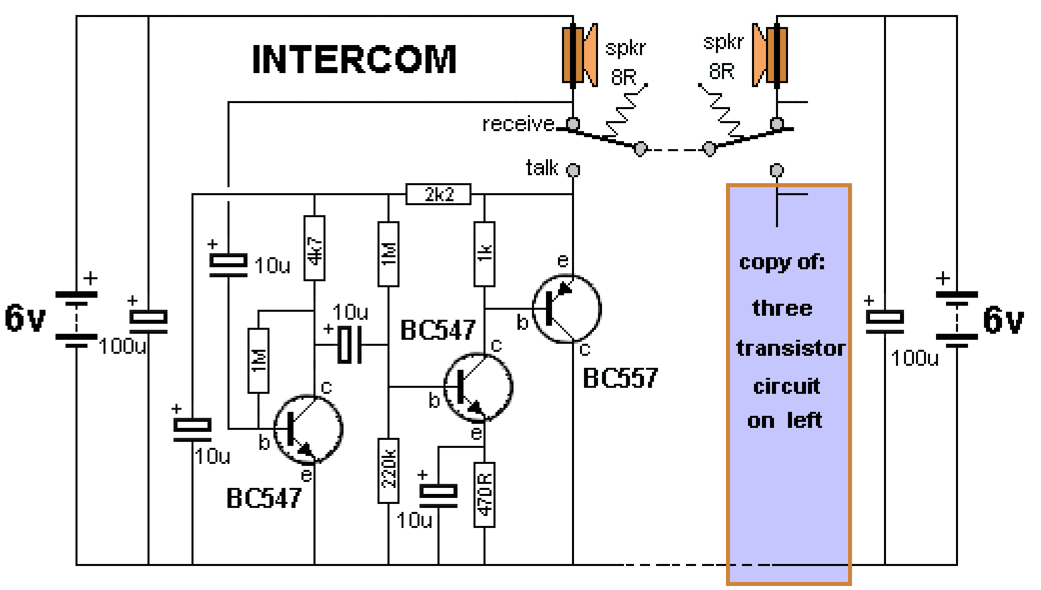
CLAP SWITCH

This circuit toggles the LEDs each time it detects a clap or tap or short whistle.
The second 10u is charged via the 5k6 and 33k and when a sound is detected, the negative excursion of the waveform takes the positive end of the 10u towards the 0v rail. The negative end of the 10u will actually go below 0v and this will pull the two 1N4148 diodes so the anode ends will have near to zero volts on them.
As the voltage drops, the transistor in the bi-stable circuit that is turned on, will have 0.6v on the base while the transistor that is turned off, will have zero volts on the base.
As the anodes of the two signal diode are brought lower, the transistor that is turned on, will begin to turn off and the other transistor will begin to turn on via its 100u and 47k.
As it begins to turn on, the transistor that was originally turned on will get less "turn-on" from its 100u and 47k and thus the two switch over very quickly. The collector of the third transistor can be taken to a buffer transistor to operate a relay or other device.
See a simple **Clap Switch** using a CD4017 IC in **100 IC Circuits**.
http://www.talkingelectronics.com/projects/100%20IC%20Circuits/1-100_IC-Ccts.html



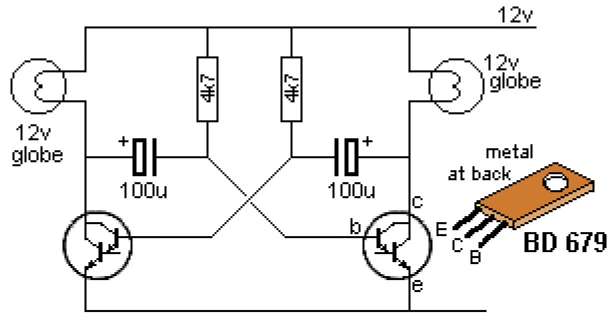
INTERCOM

Here is a 2-station intercom using common 8R mini speakers. The "press-to-talk" switches should have a spring-return so the intercom can never be left ON. The secret to preventing instability (motor-boating) with a high gain circuit like this is to power the speaker from a separate power supply! You can connect an extra station (or two extra stations) to this design.



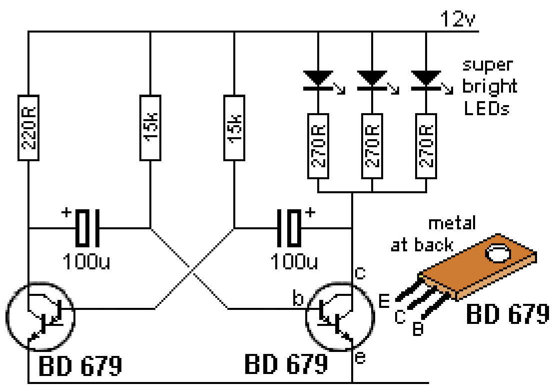
Request from Kim Edwards:
Please analyse this circuit for me.
The circuit is not normal as it must consume no current when sitting around and either end must be able to call the other end.
Start with the first transistor. It is self-biased with about half rail voltage on the collector.
The second transistor is self-biased with about 1v on the base (via the 220k and 1M). 0.4v across 470R makes about 1v across the 1k resistor.
The emitter of the BC557 will be about 0.4v lower than supply-rail.
This will produce about 1v p-p output via the speaker.
Increasing the 220k to 470k will increase the volume. The 10u to the speaker allows AC signal to enter the amplifier and the 10u on the supply-rail keeps the voltage from fluctuating too much as the supply is coming via the speaker. The 100u improves the current from the battery when the battery is weak.

WARNING BEACON



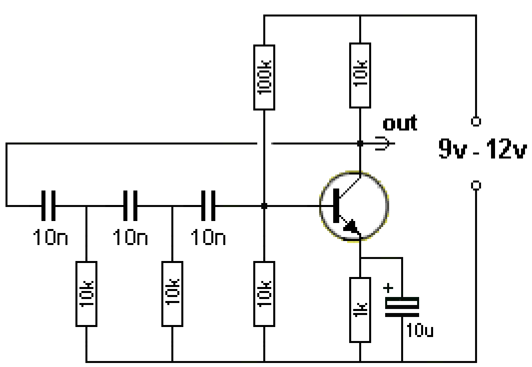
Here is a 12v Warning Beacon suitable for a car or truck break- down on the side of the road. The key to the operation of the circuit is the high gain of the Darlington transistors. The circuit must be kept "tight" (thick wires) to be sure it will oscillate.
A complete kits of parts and PC board costs $5.00 plus postage from: Talking Electronics. Email **HERE** for details.

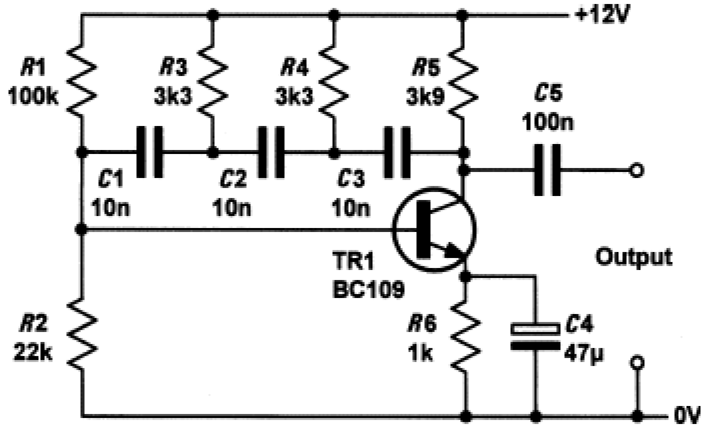
Here is the modification for 3-5 super-bright LEDs:



Click HERE for **LED Turning Indicator** project.

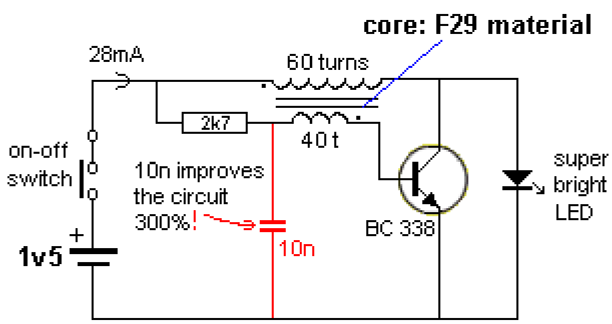
PHASE-SHIFT OSCILLATOR also called SINEWAVE OSCILLATOR



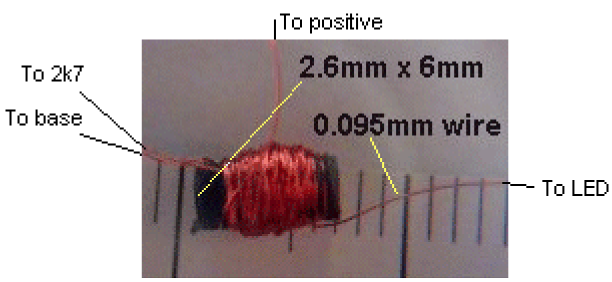


These circuits produces a sinewave very nearly equal to rail voltage.
The important feature is the need for the emitter resistor and 10u /47u bypass electrolytic. It is a most-important feature of the circuit. It provides reliable start-up and guaranteed operation. For 6v operation, the 100k is reduced to 47k.
The three 10n capacitors and two 10k resistors (actually 3) determine the frequency of operation (700Hz).
The 100k and 10k base-bias resistors can be replaced with 2M2 between base and collector.
This type of circuit can be designed to operate from about 10Hz to about 200kHz.
Both these circuits are NOT VERY RELIABLE. They work with some transistors better than others. They stop working when you touch some of the parts. The frequency changes when you add a 100u across the power rails. They are too fiddly to be recommended. Place a piezo diaphragm across the collector load and experiment yourself. Try changing the 1k and try 6v to 12v to see what I mean.

BLOCKING OSCILLATOR also called FLYBACK OSCILLATOR



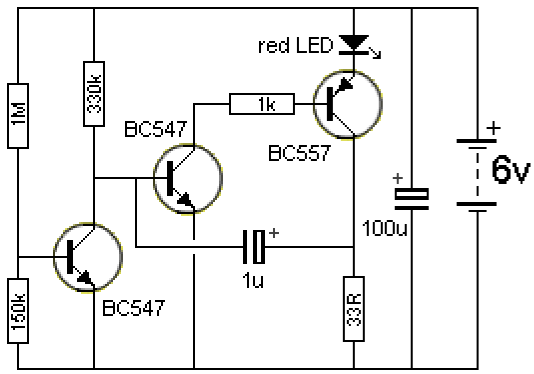
LED TORCH CIRCUIT



Transformer Details

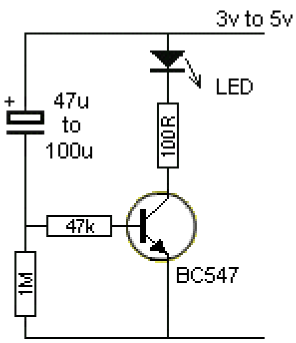
The circuit produces high voltage pulses (spikes) of about 40v p-p (when the LED is not connected), at a frequency of 200kHz. The super-bright LED on the output absorbs the pulses and uses the energy to produce illumination. The voltage across the LED will be about 3.6v
The winding to the base is connected so that it turns the transistor ON harder until it is saturated. At this point the flux cannot increase any more and the transistor starts to turn off. The collapsing magnetic field in the transformer produces a very high voltage and that's why we say the transformer operates in FLYBACK mode.
This type of circuit will operate from 10kHz to a few MHz.

LOW VOLTAGE FLASHER



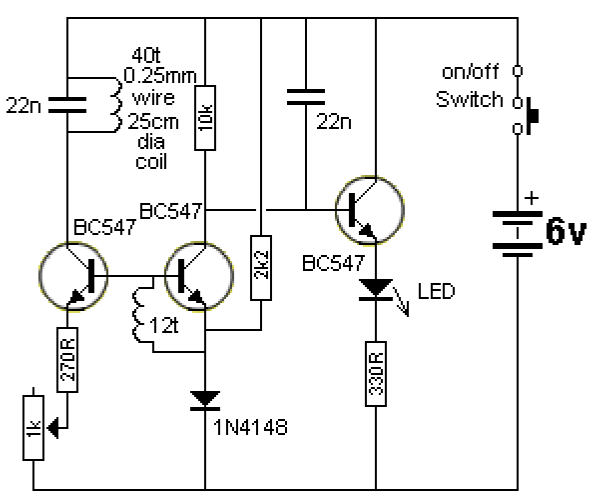
This circuit flashes when the voltage drops to 4v. The voltage "set-point" can be adjusted by changing the 150k on the base of the first transistor.

POWER ON



This LED illuminates for a few seconds when the power is turned on. The circuit relies on the 47u discharging into the rest of the circuit so that it is uncharged when the circuit is turned on again.

CAR LOOP DETECTOR

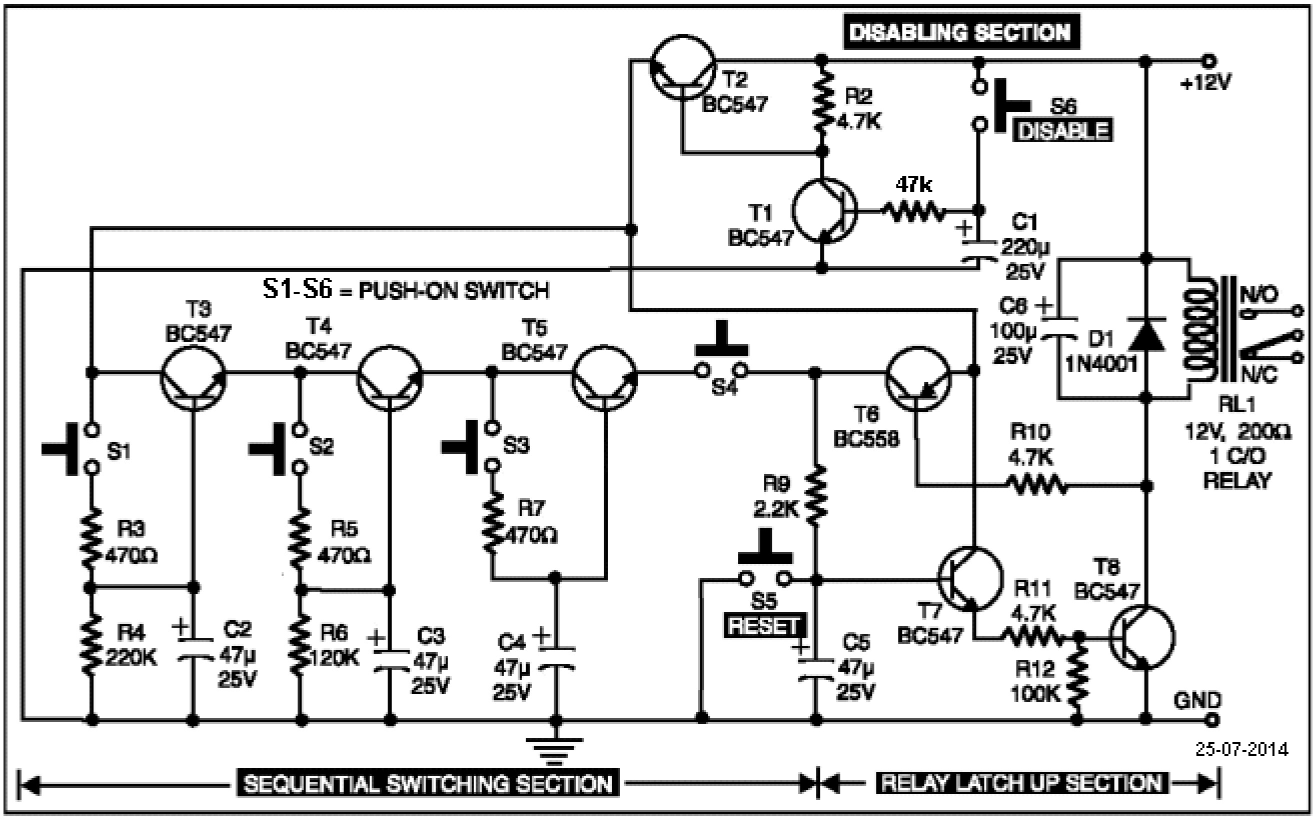


VEHICLE DETECTOR

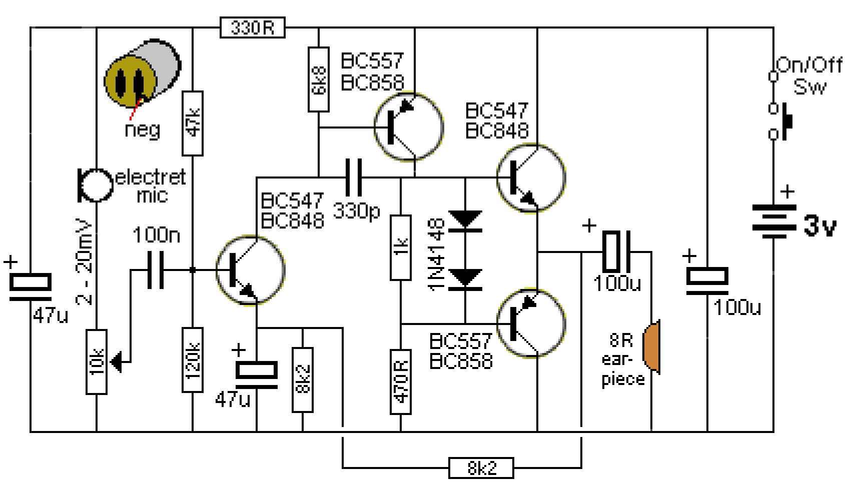
A 25cm dia coil (consisting of 40 turns and 12 turns) is placed in the centre of a driveway (between two sheets of plastic). When a vehicle is driven over the coil, it responds by the waveform collapsing. This occurs because the tank circuit made up of the 40 turns is receiving just enough feedback signal from the 12 turns to keep it oscillating. When metal is placed near the coil, it absorbs some of the electromagnetic waves and

the amplitude decreases. This reduces the amplitude in the 12 turns and the oscillations collapses. The second transistor turns off and the 10k pulls the base of the third transistor (an emitter-follower) to the 6v rail and turns on the LED.

ALARM USING 4-BUTTONS



To open the lock, buttons S1, S2, S3, and S4 must be pressed in this order. They must be pressed for more than 0.7 seconds and less than 1.3 seconds.
Reset button S5 and disable button S6 are also included with the other buttons and if the disable button is pressed, the circuit will not accept any code for 60 seconds. Each of the 3v3 zeners can be replaced with two red LEDs and this will show how you are progressing through the code. Make sure the LEDs are not visible to other users.



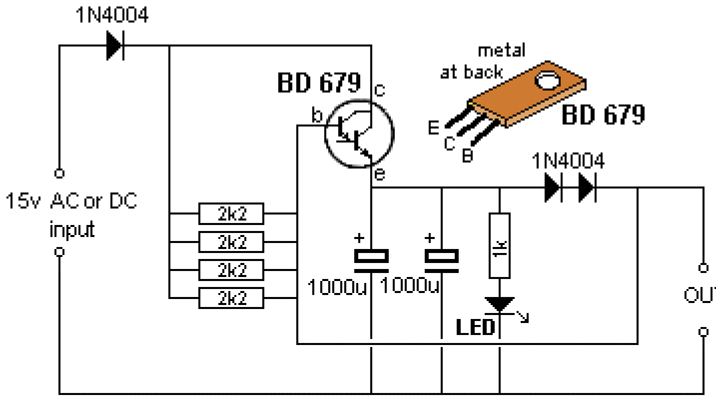
AUDIO AMPLIFIER (mini)

This project is called "mini" because its size is small and the output is small.
It uses surface mount technology.

HOW THE CIRCUIT WORKS

The output is push-pull and consumes less than 3mA (with no signal) but drives the earpiece to a very loud level when audio is detected.
The whole circuit is DC coupled and this makes it extremely difficult to set up. Basically you don't know where to start with the biasing. The two most critical components are 8k2 between the emitter of the first transistor and 0v rail and the 470R resistor.
The 8k2 across the 47u sets the emitter voltage on the BC 547 and this turns it on. The collector is directly connected to the base of a BC 557, called the driver transistor. Both these transistors are now turned on and the output of the BC 557 causes current to flow through the 1k and 470R resistors so that the voltage developed across each resistor turns on the two output transistors. The end result is mid-rail voltage on the join of the two emitters.

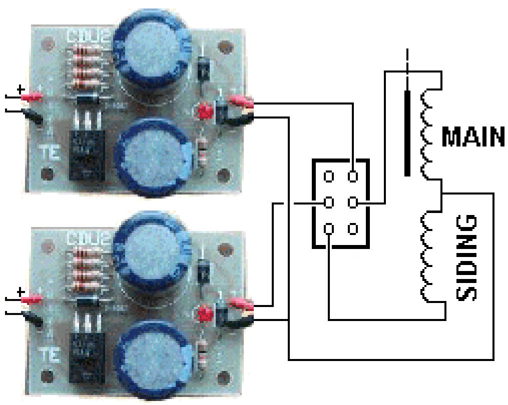
The 8k2 feedback resistor provides major negative feedback while the 330p prevents high-frequency oscillations occurring.

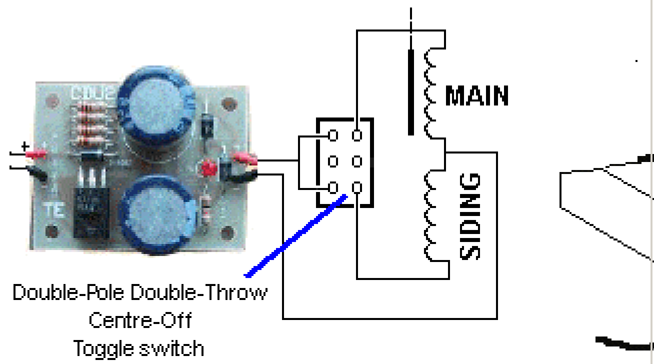


CAPACITOR DISCHARGE UNIT MkII (CDU2)

This project is available as a kit for $10.80 plus $6.50 post. email [Talking Electronics] for details.

CAPACITOR DISCHARGE UNIT MkII





This circuit will operate a two-solenoid point-motor and prevent it overheating and causing any damage. The circuit produces energy to change the points and ceases to provide any more current. This is carried out by the switching arrangement within the circuit, by sampling the output voltage.
If you want to control the points with a DPDT toggle switch or slide switch, you will need two CDU2 units.

HOW THE CIRCUIT WORKS

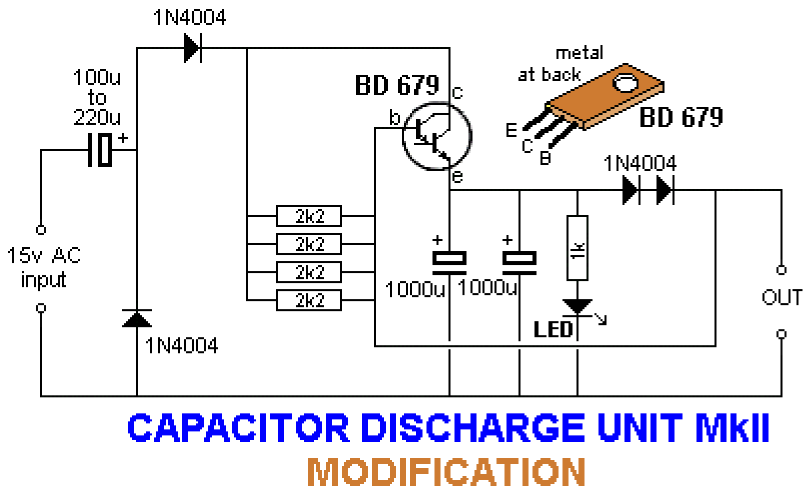
The circuit is supplied by 16v AC or DC and the diode on the input is used to rectify the voltage if AC is supplied. If nothing is connected to the output, the base of the BD679 is pulled high and the emitter follows. This is called an emitter-follower stage. The two 1,000u electrolytics charge and the indicator LED turns on. The circuit is now ready.
When the Main or Siding switch is pressed, the energy from the electrolytics is passed to the point motor and the points change. As the output voltage drops, the emitter-follower transistor is turned off and when the switch is released, the electrolytics start to charge again.

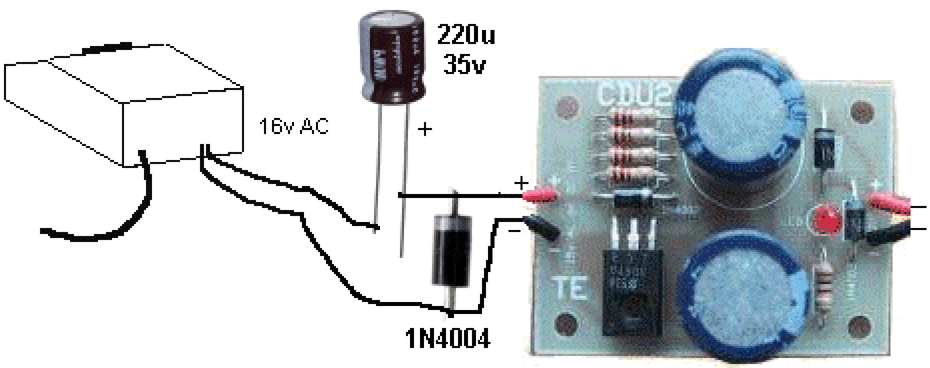
The point-motor can be operated via a Double-Pole Double-Throw Centre-Off toggle switch, providing the switch is returned to the centre position after a few seconds so that the CDU unit can charge-up.

CAPACITOR DISCHARGE UNIT MkII (CDU2) - modification

If your transformer does not supply 15vAC to 16vAC, you can increase the input voltage by adding

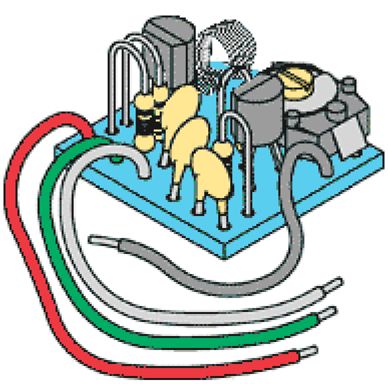
a 100u to 220u electrolytic and 1N4004 diode to the input to create a voltage doubling arrangement. You can also change one or both the 1,000u electrolytics for 2,200u. This will deliver a much larger pulse to the point-motor and guarantee operation.

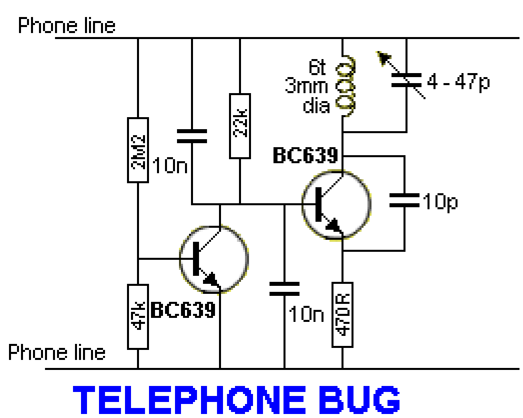




PHONE BUG see also Phone Transmitter 1 and 2 (1-100 circuits)

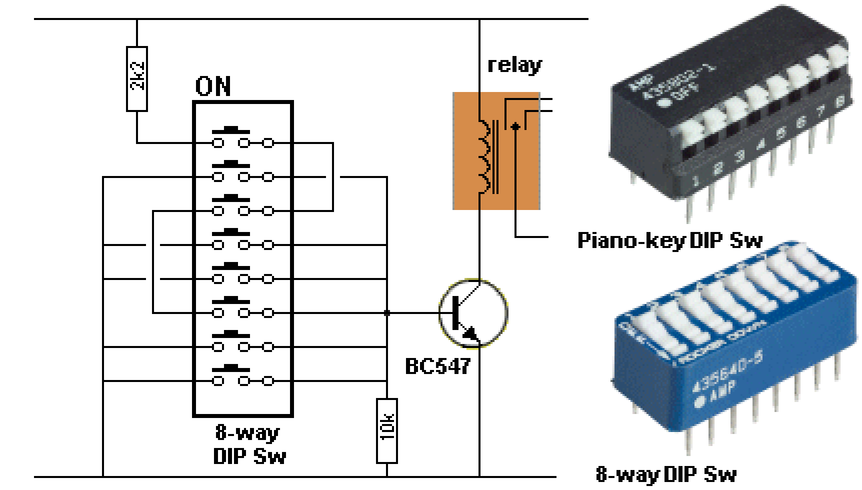
This circuit connects to a normal phone line and when the voltage drops to less than 15v, the first transistor is turned off and enables the second transistor to oscillate at approx 100MHz and transmit the phone conversation to a nearby FM radio. The transistors must be 65v devices. Do not use BC547.





CODE LOCK

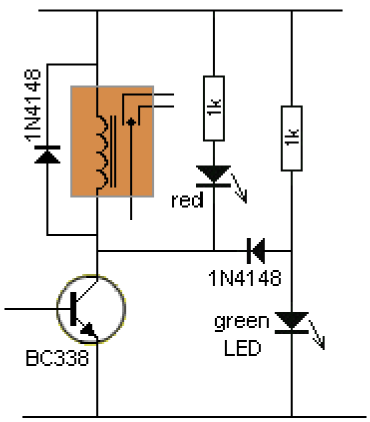
This circuit turns on a relay when the correct code is entered on the 8-way DIP switches. Two different types of DIP switches are shown.
Keep the top switch off and no current will be drawn by the circuit.
There are 256 different combinations and because the combination is in binary, it would be very difficult for a burglar to keep up with the settings of the switches.



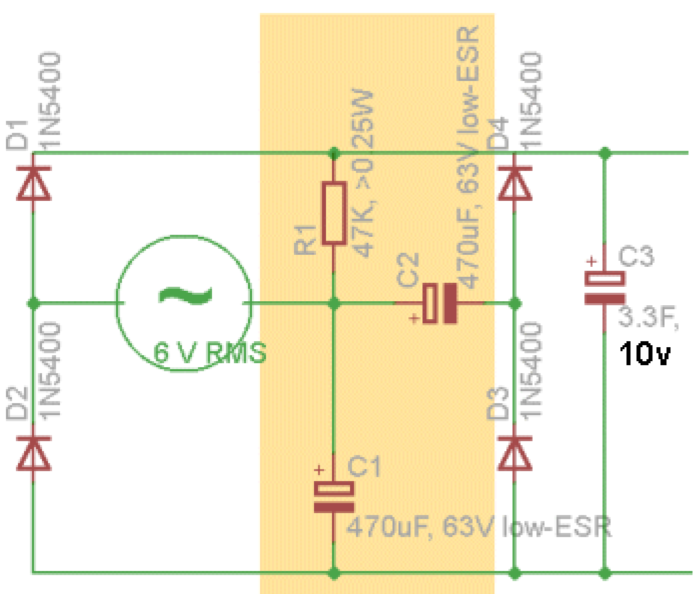
CODE LOCK

LEDS SHOW RELAY STATE

The green LED indicates the relay is not energised and the red LED shows the relay is energised.



VOLTAGE DOUBLER

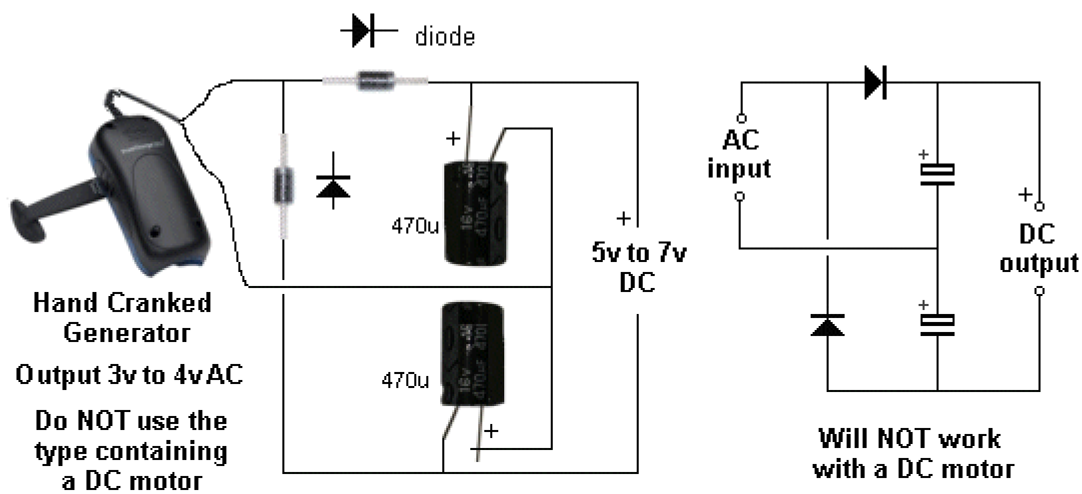


This is a voltage doubler circuit from a bicycle dynamo design found on the web. The dynamo produces 6v AC and charges a 3.3FARAD super cap via 2 diodes and an electrolytic. As you will see, C2, D3 and D4 are not needed and can be removed.
This is how the circuit works.
The voltage at the mid point of diodes D1 and D2 can fall to -0.6v and rise to rail voltage plus 0.6v without any current being supplied from the dynamo.
When the voltage rises more than 0.6v above rail voltage, the dynamo needs to deliver current and this will allow the rail voltage to increase. We start with the dynamo producing negative from the left side and positive on the right side.
The left side will fall to -0.6v below the 0v rail and the right side will charge C1 and C2 will simply rise in exactly the same manner as we described the left side of the dynamo being able to rise.
Suppose C1 charges to about 7v (which it will be able to do after a few cycles). The voltage from the dynamo now reverses and the left side is positive and the right side is negative. The right side is already sitting at a potential of 7v (via C1) and as the left side increases,

it raises the rail voltage higher by an amount that could be as high as 7v minus 0.6v.
The actual rail voltage will not be as high as this as the 3.3 Farad capacitor will be charging, but if energy is not taken from the circuit it will rise to nearly 14v or even higher according to the peak voltage delivered by the dynamo.
When the dynamo is delivering energy to the positive rail, it is "pushing down" on the C1 and some of its stored energy is also delivered. This means it will have a lower voltage across it when the next cycle comes around. C2, D3 and D4 are not needed and can be removed. In fact, C1 will always have rail voltage on it due to the 47 resistor, so the voltage doubling will start as soon as the dynamo operates.

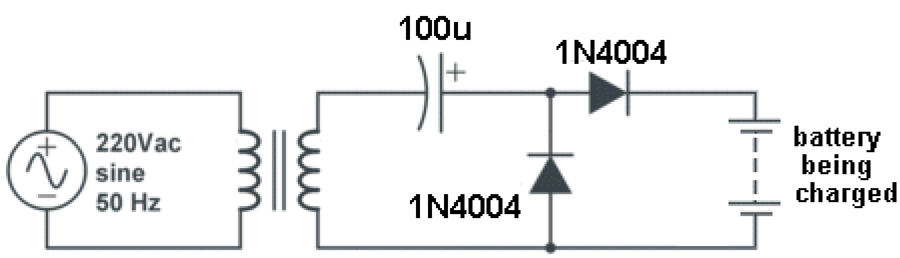
DYNAMO VOLTAGE DOUBLER

Here is a simple circuit to increase the voltage from a BICYCLE DYNAMO (or HAND CRANKED GENERATOR that has a spinning magnet - NOT a DC motor) and change the AC voltage it produces, to DC, and charge a small battery:



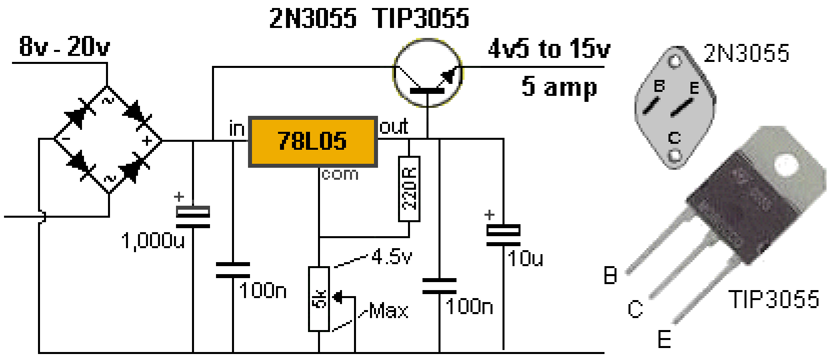
BATTERY-CHARGER DOUBLER

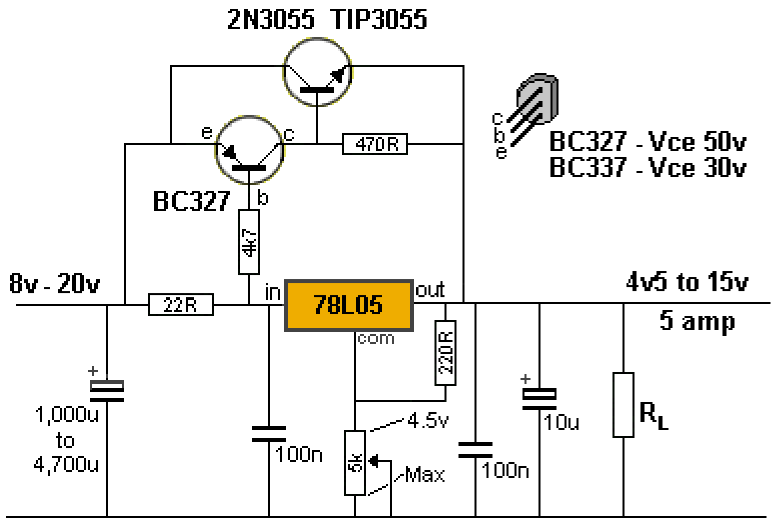
This circuit will charge a battery from an AC source where the AC voltage is too low to charge the battery.
This circuit increases the voltage and rectifies it to produce pulsing DC. The 100u electrolytic limits the current and can be increased to 1,000u to provide a higher current.
Even though the voltage will be increased to about twice the previous voltage, this will not affect the battery as the important quantity is CURRENT and TIME. You need to monitor the battery and determine when it is fully charged.



Adjustable High Current Regulated Power Supply

There are two ways to add a 2N3055 (TIP3055) as the pass transistor for a high current power supply. This is handy as most hobbyists will have one of these in their parts box.



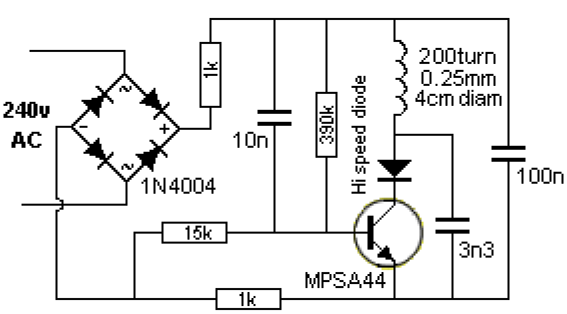


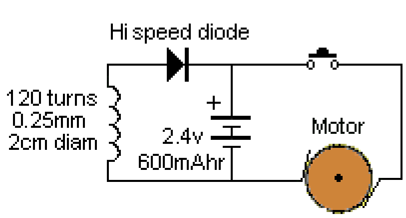
RL must be low enough to guarantee at least a 30mA. It can be a separate resistor or part of the actual load.

INDUCTIVELY COUPLED POWER SUPPLY

This circuit is from an Interplak Model PB-12 electric toothbrush.

A coil in the charging base (always plugged in and on) couples to a mating coil in the hand unit to form a step down transformer. The MPSA44 transistor is used as an oscillator at about 60 kHz which results in much more efficient energy transfer via the air core coupling than if the system were run at 50 or 60Hz. The amplitude of the oscillations varies with the full wave rectified 100Hz or 120Hz unfiltered DC.

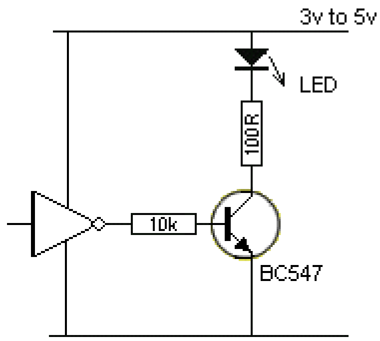


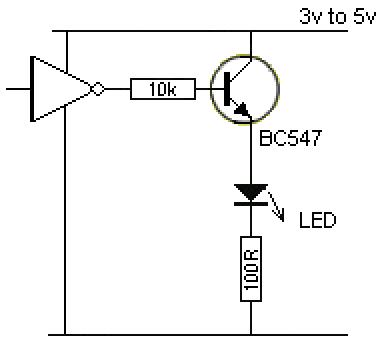


The battery charger is nothing more than a diode to rectify the signal from the 120 turn coil in the charging base. Thus the battery is in constant trickle charge as long as the hand unit is in the base. The battery pack is a pair of 600mAhr AA NiCd cells.

POWERING A LED

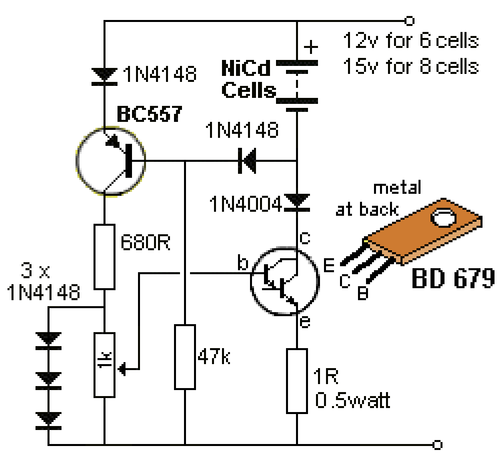
Sometimes the output of a gate does not have sufficient current to illuminate a LED to full brightness.
Here are two circuits. The circuits illuminate the LED when the output signal is HIGH. Both circuits operate the same and have the same effect on loading the output of the gate.





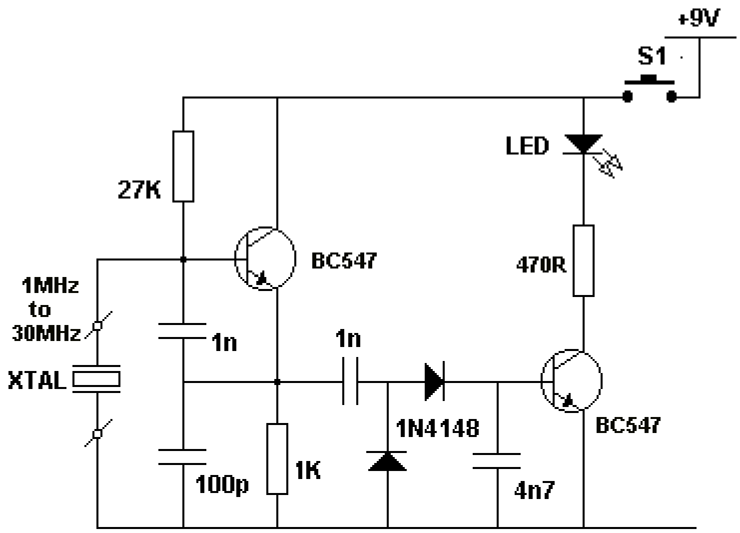
NiCd BATTERY CHARGER

This NiCd battery charger can charge up to 8 NiCd cells connected in series. This number can be increased if the power supply is increased by 1.65v for each additional cell. If the BD679 is mounted on a good heatsink, the input voltage can be increased to a maximum of 25v. The circuit does not discharge the battery if the charger is disconnected from the power supply.
Usually NiCd cells must be charged at the 14 hour rate. This is a charging current of 10% of the capacity of the cell for 14 hours. This applies to a nearly flat cell. For example, a 600 mAh cell is charged at 60mA for 14 hours. If the charging current is too high it will damage the cell. The level of charging current is controlled by the 1k pot from 0mA to 600mA. The BC557 is turned on when NiCd cells are connected with the right polarity. If you cannot obtain a BD679, replace it with any NPN medium power Darlington transistor having a minimum voltage of 30v and a current capability of 2A. By lowering the value of the 1 ohm resistor to 0.5 ohm, the maximum output current can be increased to 1A.



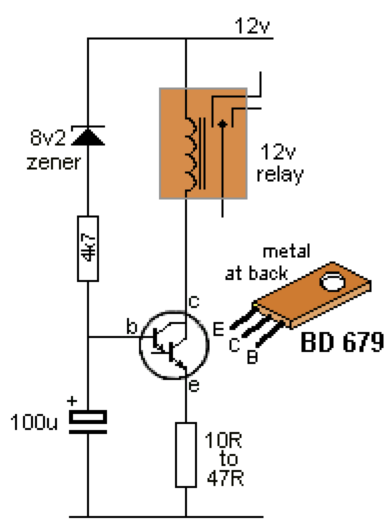
CRYSTAL TESTER

This circuit will test crystals from 1MHz to 30MHz. When the crystal oscillates, the output will pass through the 1n capacitor to the two diodes. These will charge the 4n7 and turn on the second transistor. This will cause the LED to illuminate.



LOW VOLTAGE CUT-OUT

This circuit will detect when the voltage of a 12v battery reaches a low level. This is to prevent deep-discharge or maybe to prevent a vehicle battery becoming discharged to a point where it will not start a vehicle. This circuit is different to anything previously presented. It has HYSTERESIS. Hysteresis is a feature where the upper and lower detection-points are separated by a gap.
Normally, the circuit will deactivate the relay when the voltage is 10v and when the load is removed. The battery voltage will rise slightly by as little as 50mV and turn the circuit ON again. This is called "Hunting." The off/on timing has been reduced by adding the 100u. But to prevent this totally from occurring, a 10R to 47R is placed in the emitter lead. The circuit will turn off at 10v but will not turn back on until 10.6v when a 33R is in the emitter.
The value of this resistor and the turn-on and turn-off voltages will also depend on the resistance of the relay.

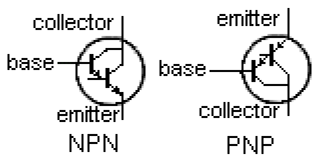


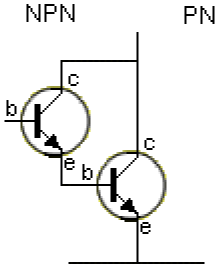
THE DARLINGTON TRANSISTOR

Normally a single transistor-stage produces a gain of about 100.
If you require a very high gain, two stages can be used. Two transistors can be connected connected in many ways and the simplest is DIRECT COUPLING. This is shown in the circuit below. An even simpler method is to combine two transistors in one package to form a single transistor with very high gain, called DARLINGTON TRANSISTOR.
These are available as:
BD679 NPN-Darlington

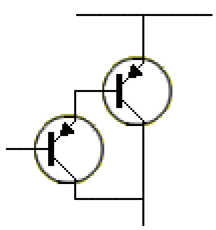
2N6284 NPN-Darlington
BC879 NPN-Darlington
BC880 PNP-Darlington
TIP122 NPN-Darlington
TIP127 PNP-Darlington

These devices consist of two NPN or PNP transistors but the same result can be obtained by using a PNP/NPN pair. This is called a Sziklai pair. This arrangement will have to be created with two separate transistors.
The Darlington transistor can also be referred to as:
"Super Transistor, Super Alpha Pair, Sziklai pair, Complementary Pair,
Darlington transistors have a gain of 1,000 to 30,000. When the gain is 1,000:1 an input of 1mA will produce a current of 1 amp in the collector-emitter circuit.
The only disadvantage of a Darlington Transistor is the minimum voltage between collector-emitter when fully saturated. It is 0.6v to 1.5v depending on the current through the transistor.
A normal transistor has a collector-emitter voltage (when saturated) of 0.2v to 0.5v. The higher voltage means the transistor will heat up more and requires good heatsinking. In addition, a Darlington transistor needs 1.2v between base and emitter before it will turn on. A Sziklai pair only requires 0.6v for it to turn on.

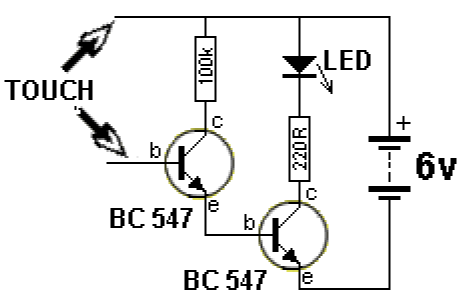




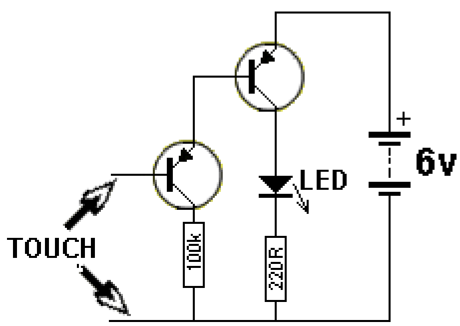
Darlington using two NPN transistors



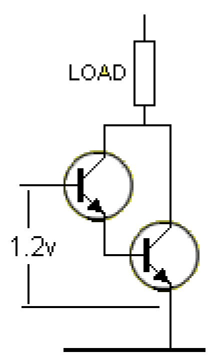
Darlington using two PNP transistors



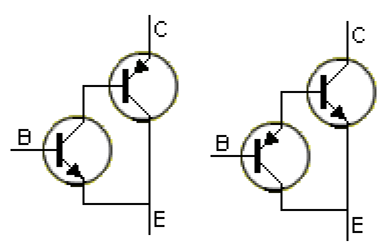
Circuit shows the HIGH GAIN of two NPN transistors



Circuit shows the HIGH GAIN of two PNP transistors



Super Alpha Pair
NPN

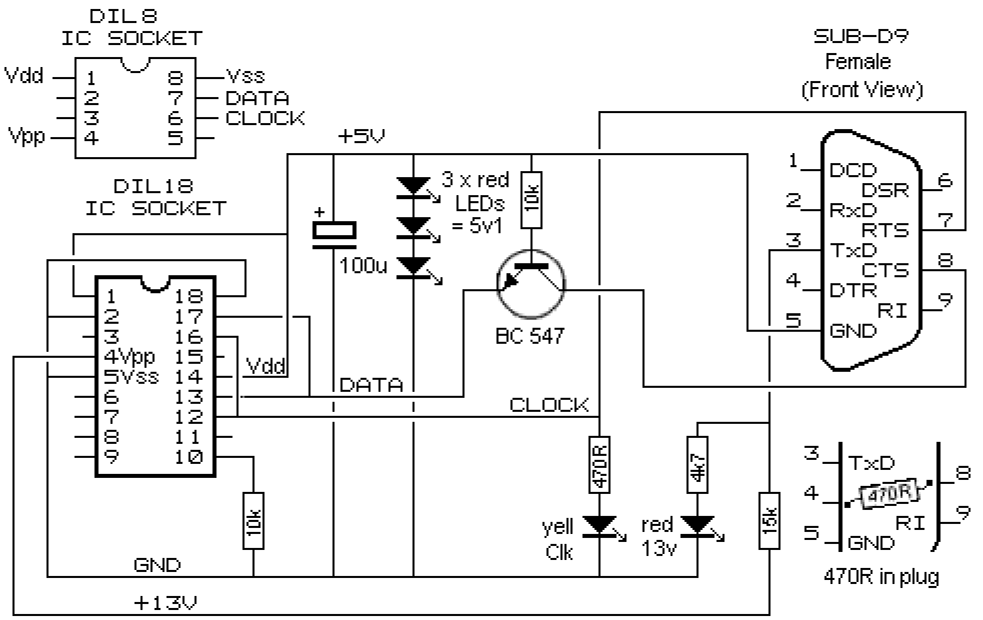


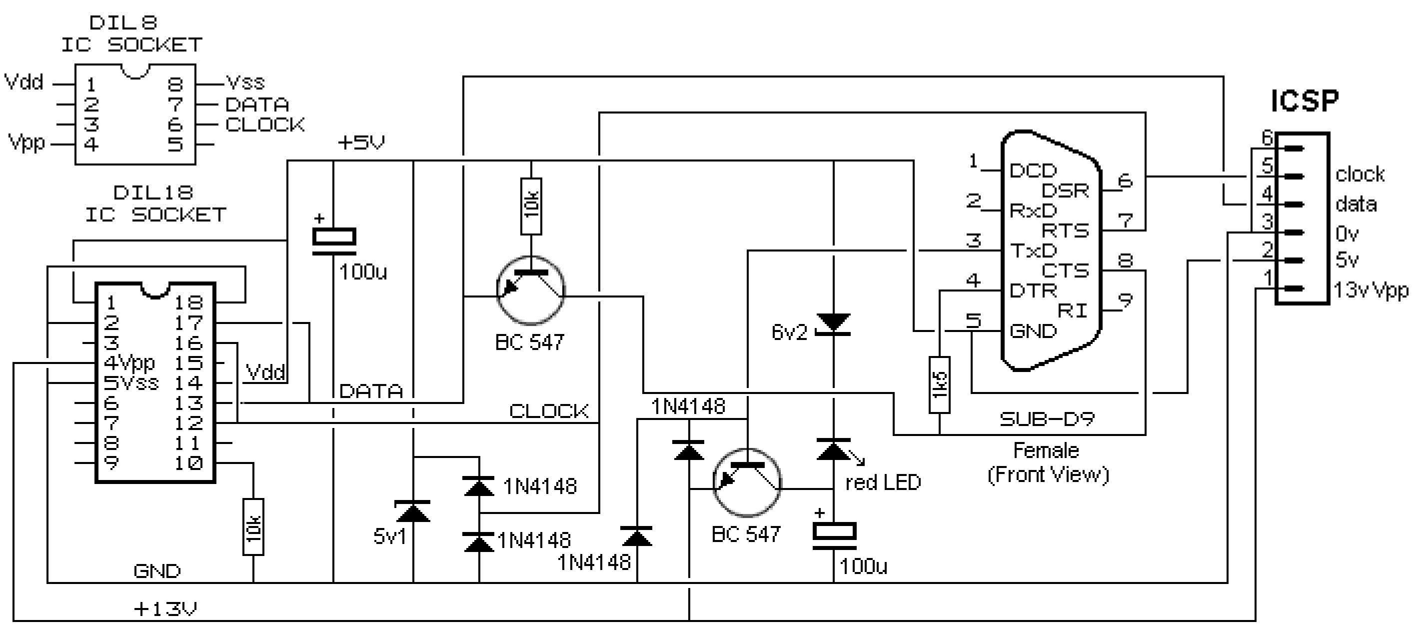
Sziklai Pair Sziklai Pair

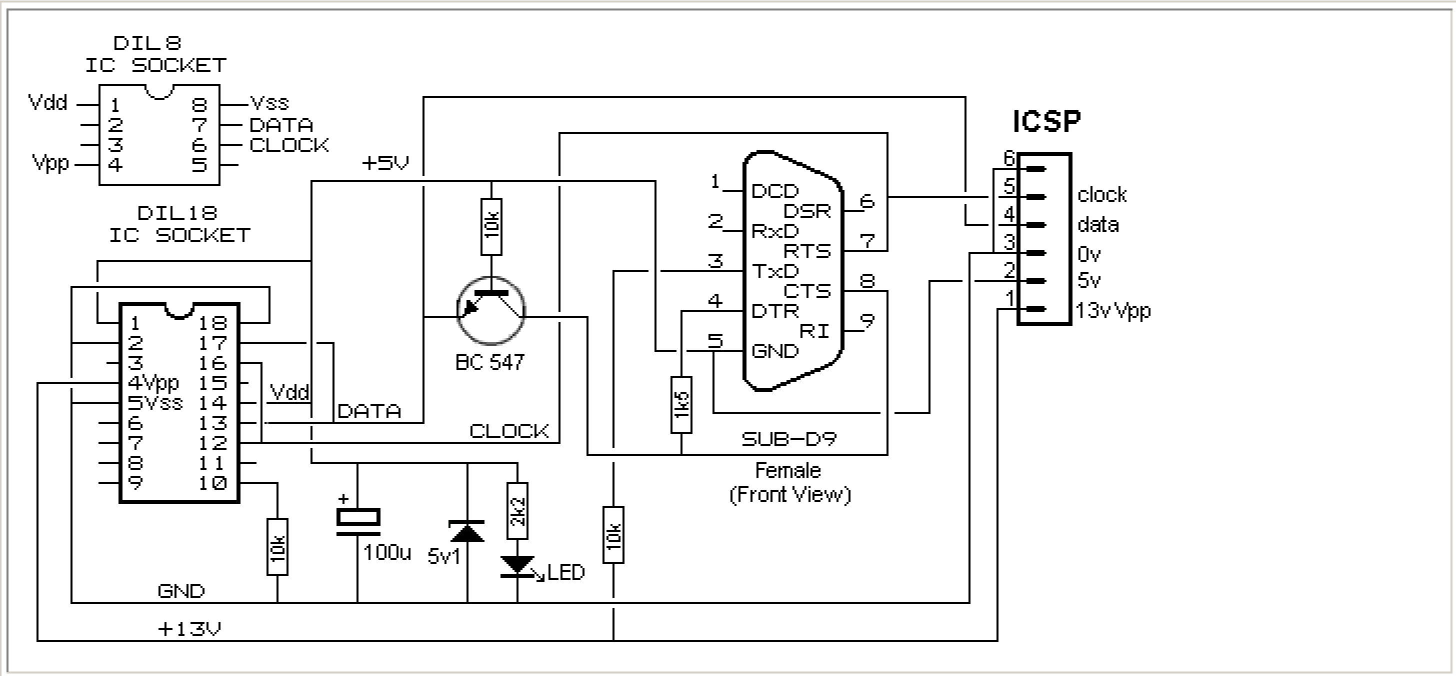
PIC PROGRAMMER

The simplest programmer to program PIC chips is connected to your computer via the serial port. This is a 9-pin plug/socket arrangement called a SUB-D9 with the male plug on the computer and female on a lead that plugs into the computer.
The signals that normally appear on the pins are primary designed to talk to a modem but we use the voltages and the

voltage-levels to power a programmer. The voltages on the pins are **On** or **Off**. On (binary value "1") means the pin is between -3 and -25 volts, while Off (binary value "0") means it is between +3 and +25 volts, depending on the computer. But many serial ports produce voltages of only +8v and -8V and the programmer circuit uses this to produce a voltage of about 13.5v to put the PIC chip into programming mode. This is the minimum voltage for the programmer to work. Any computers with a lower voltage cannot be used. That's why the circuit looks so unusual. It is combining voltages to produce 13v5.
Here are two circuits.
The first circuit is used in our PIC PROGRAMMER - 12 parts project.
Circuit 2 uses more components to produce the same result and circuit 3 uses less components.

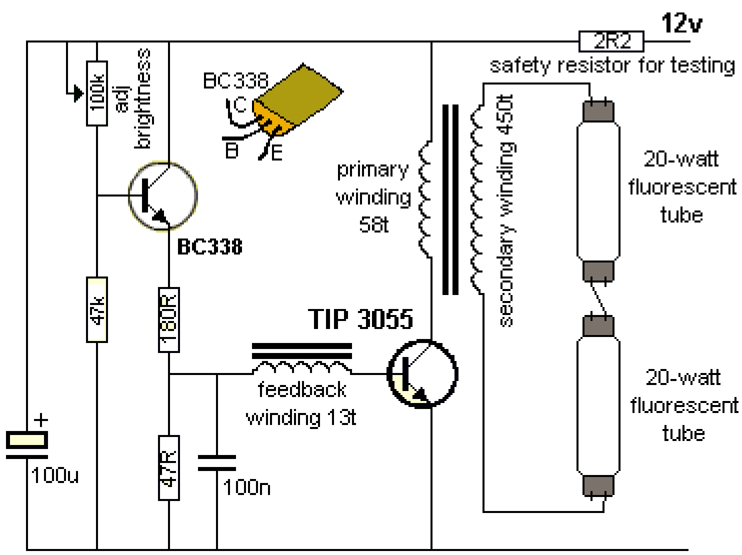




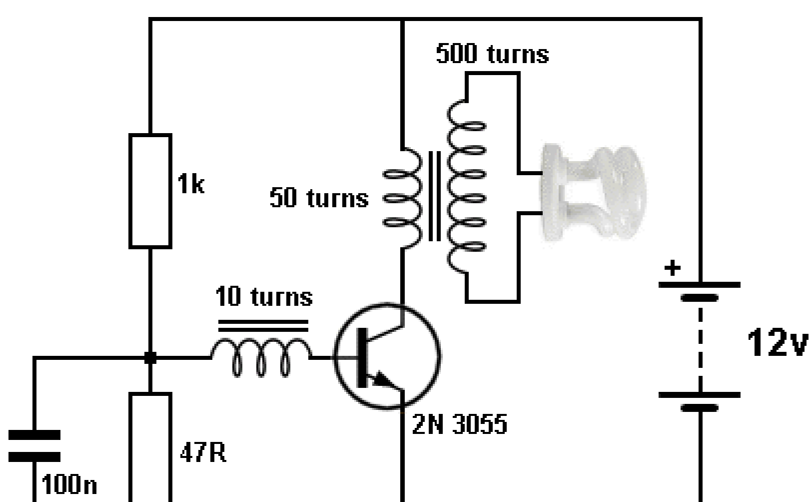


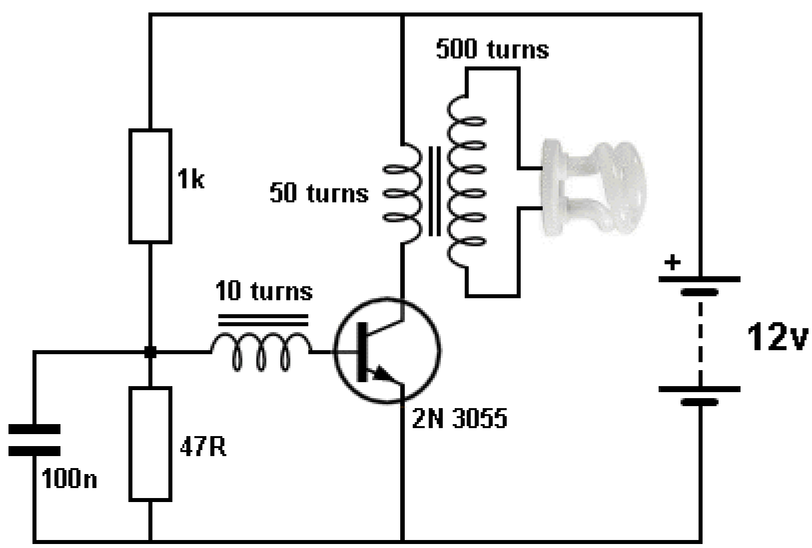
FLUORESCENT INVERTER

The simple circuit will drive up to two 20watt fluoro tubes from a 12v supply.
The circuit also has a brightness adjustment to reduce the current from the battery. See Fluorescent Inverter article for more details.



5 watt CFL Driver





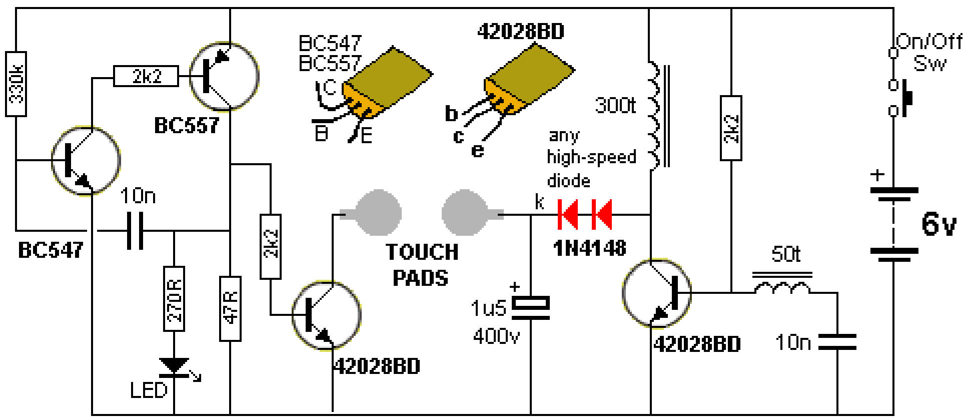
Both circuits are almost identical and this circuit has the brightness section removed and the 100u removed. The removal of the 100u reduces the brightness but it also reduces the current from 500mA to 250mA to make a very efficient circuit for an emergency situation.
Note: Driving a 20 watt tube (normal 2-foot tube) produces much-more illumination than a 5 watt CFL.

This circuit will drive a 5watt CFL tube from an old CFL lamp from 6v or 12v. It makes a very handy emergency light.
The transformer is made by winding 500 turns for the secondary. This consists of winding about 10 turns on top of each other before advancing along the rod. The rod can be round or flat, from an old AM radio. It is called a ferrite rod. The 500 turns have to be added before reaching the end and this means 100 turns has to take up 1/5th of the distance. This reduces the voltage between the turns as the enamel will only withstand 100 volts.
Before you start winding, use at least 3 layers of “sticky-tape” to prevent the high voltage shorting to the rod.
The size of the wire is not important and anything 0.25mm or thinner will be suitable. After winding the secondary, the primary is 50 turns and the feedback is 10 turns.
The primary can be 0.5mm wire and the feedback 0.25mm.
Connect the transistor, components and tube and turn the circuit ON very briefly. If the tube does not illuminate immediately, reverse the wires to the feedback winding.
The transistor must be 2N 3055 (or the plastic version, TIP 3055). It will get warm when illuminating the lamp and needs to be heatsinked. The lamp must not be removed as the circuit will overload and damage the transistor.
The circuit takes 250mA when driving a 5 watt CFL (or 18 watt fluorescent tube) on 12v supply. The 1k base resistor can be reduced to 820R and the brightness will increase slightly but the current will increase to 500mA.
The circuit is more-efficient on 6v. The 1k base resistor is reduced to 220R and the transistor remains cool.

ZAPPER - 160v

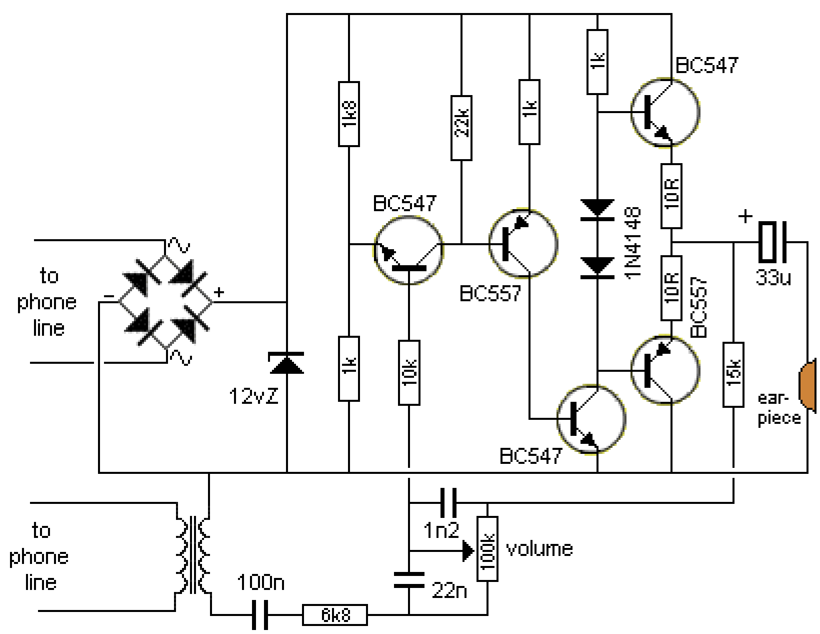
This project will give you a REAL SHOCK. It produces up to 160v and outputs this voltage for a very short period of time.
The components are taken from an old CFL (Compact Fluorescent Lamp) as the transistors are high voltage types and the 1u5 electro @400v can also be taken from the CFL as well as the ferrite core for the transformer.
The CFL has a 1.5mH choke with a DC resistance of 4 ohms. This resistance is too low for our circuit and the wire is removed and the core rewound with 50 turns for the feedback winding and 300 turns of 0.1mm wire to produce a winding with a resistance of about 10 ohms for the primary.
The oscillator is "flyback" design that produces spikes of about 160v and these are fed to a high-speed diode (two 1N4148 diodes in series) to charge a 1u5 electrolytic to about 160v. If you put your fingers across the electrolytic you will hardly feel the voltage. You might get a very tiny tingle at the end of your fingers.

But if this voltage is delivered, then turned off, you get an enormous shock and you pull yours fingers off the touch pads.
That's what the other part of the circuit does. It turns on a high-voltage transistor for a very short period of time and this is what makes the circuit so effective.



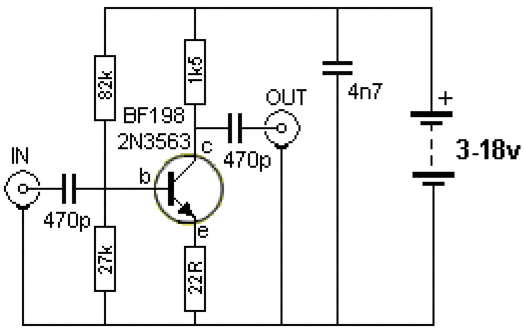
TELEPHONE AMPLIFIER

This amplifier circuit is used in all home telephones to amplify the signal from the line to the earpiece. The voltage is taken from the line via a bridge that delivers a positive rail, no matter how the phone wires are connected.
A transformer is used to pick off a signal from the phone line and this is passed through a 22n to the input of the amplifier. Negative feedback is provided by a 15k and 1n2 capacitor. The operating point for the amplifier is set by the 100k pot and this serves to provide an effect on the gain of the amplifier and thus the volume.



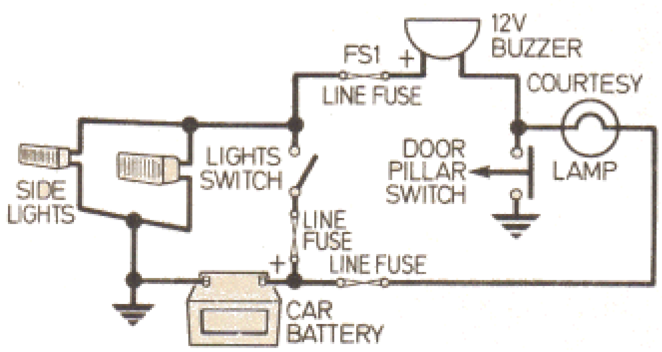
VHF AERIAL AMPLIFIER

This amplifier circuit can be used to amplify VHF television signals. The gain is between 5dB and 28dB. 300ohm twin feeder can be used for the In/Out leads.



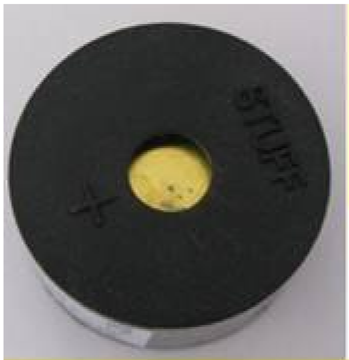
CAR LIGHTS ALERT

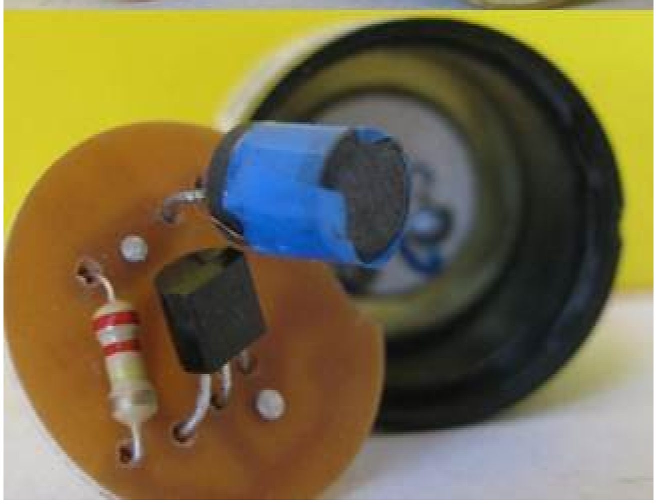
This circuit will alert the driver if the lights have been left on. A warning sound will be emitted from the 12v buzzer when the driver's door is opened and the lights are on.

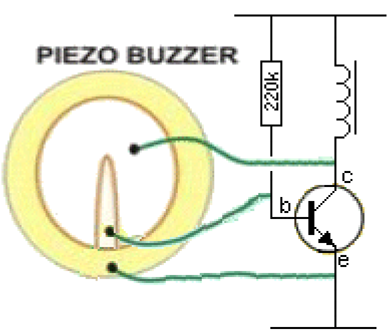


How a PIEZO BUZZER WORKS

A Piezo Buzzer contains a transistor, coil, and piezo diaphragm and produces sound when a voltage is applied. The buzzer in the circuit above is a PIEZO BUZZER.

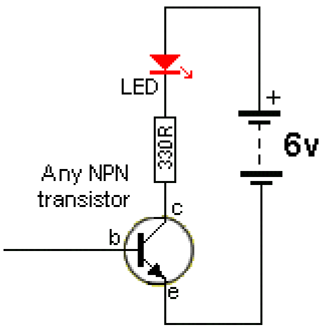






The circuit starts by the base receiving a small current from the 220k resistor. This produces a small magnetic flux in the inductor and after a very short period of time the current does not increase. This causes the magnetic flux to collapse and produce a voltage in the opposite direction that is higher than the applied voltage.
3 wires are soldered to pieces of metal on the top and bottom sides of a ceramic substrate that expands sideways when it sees a voltage. The voltage on the top surface is passed to the small electrode and this positive voltage is passed to the base to turn the transistor ON again. This time it is turned ON more and eventually the transistor is fully turned ON and the

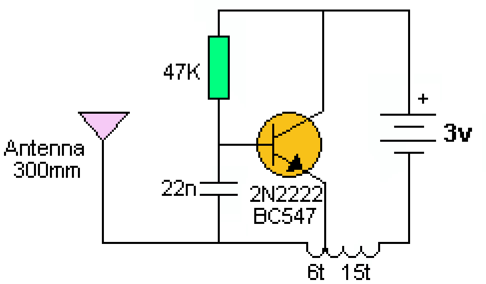
current through the inductor is not an INCREASING CURRENT by a STATIONARY CURRENT and once again the magnetic flux collapses and produces a very high voltage in the opposite direction. This voltage is passed to the piezo diaphragm and causes the electrode to "Dish" and produce the characteristic sound. At the same time a small amount is "picked-off" and sent to the transistor to create the next cycle.

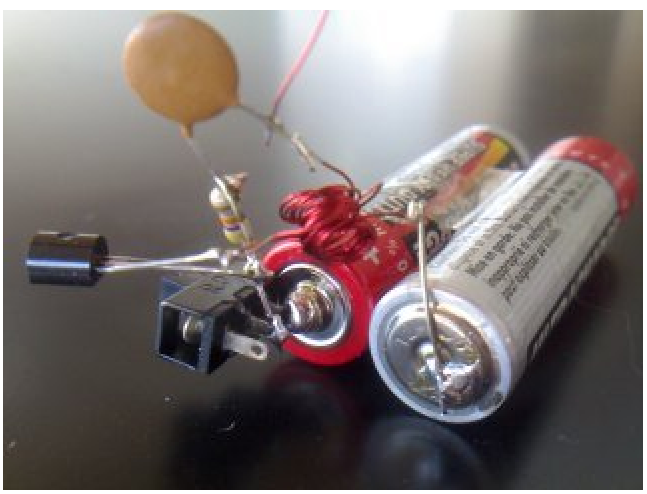


MAINS DETECTOR

This circuit detects the "Active" wire of 110v AC or 240v AC via a probe and does not require "continuity." This makes it a safe detector.
It uses the capacitance of your body to create current flow in the detecting part of the circuit and the sensitivity will depend on how you hold the insulating case of the project. No components of the circuit must be exposed as this will result in ELECTROCUTION.

SIMPLEST FM BUG

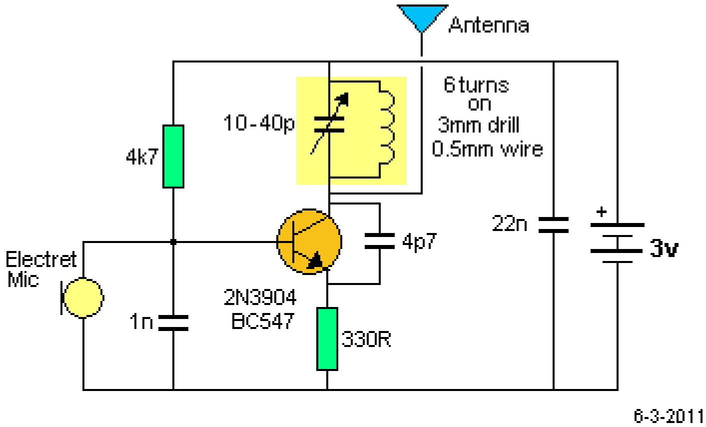




This circuit is the simplest FM circuit you can get. It has no microphone but the coil is so MICROPHONIC that it will pick up noises in the room via vibrations on a table.
The circuit does not have any section that determines the frequency. In the next circuit and all those that follow, the section that determines the frequency of operation is called the TUNED CIRCUIT or TANK CIRCUIT and consists of a coil and capacitor. This circuit does not have this feature. The transistor turns on via the 47k and this puts a pulse through the 15 turn winding. The magnetic flux from this winding passes through the 6 turn winding and into the base of the transistor via the 22n capacitor. This pulse is amplified by the transistor and the circuit is kept active.
The frequency is determined by the 6 turn coil. By moving the turns

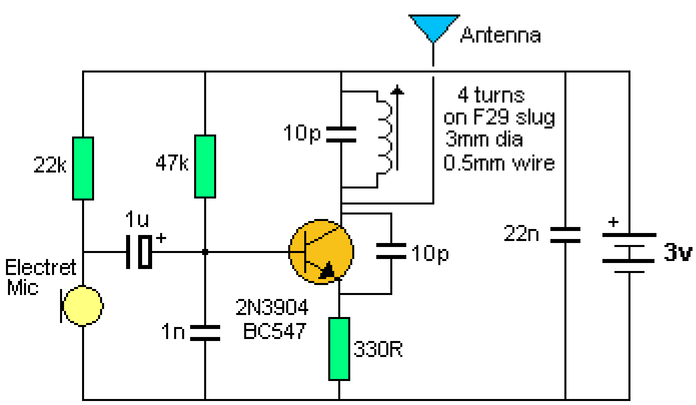
together, the frequency will decrease. The circuit transmits at 90MHz. It has a very poor range and consumes 16mA. The coil is wound on a 3mm drill and uses 0.5mm wire.

A GOOD ONE-TRANSISTOR CIRCUIT



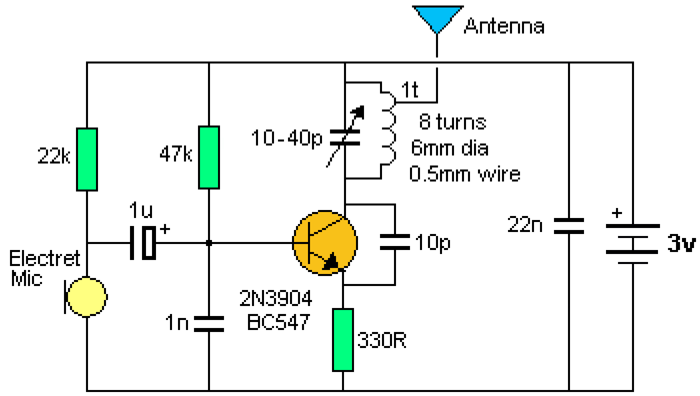
This circuit uses a TUNED CIRCUIT or TANK CIRCUIT to create the operating frequency. For best performance the circuit should be built on a PC board with all components fitted close to each other. The photo below shows the components on a PC board:

AN IMPROVED DESIGN



This design uses a "slug tuned coil" to set the frequency. This means the slug can be screwed in and out of the coil. This type of circuit does not offer any improvement in stability over the previous circuit. (In later circuits we will show how to improve stability. The main way to improve stability is to add a "buffer" stage. This separates the oscillator stage from the output.)
The antenna is connected to the **collector of the transistor** and this "loads" the circuit and will cause drift if the bug is touched. The range of this circuit is about 200 metres and current consumption is about 7mA. The microphone has been separated from the oscillator and this allows the gain of the microphone to be set via the 22k resistor. Lowering the resistor will make the microphone more sensitive. This circuit is the best you can get with one transistor.

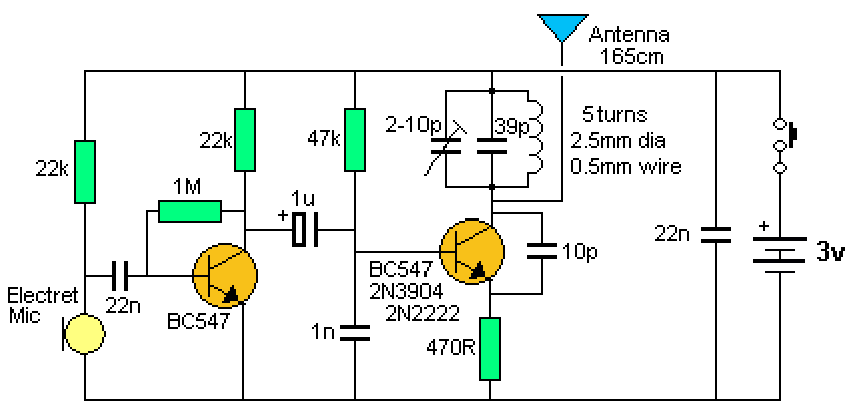
MORE STABILITY



If you want more stability, the antenna can be tapped off the top of the tank circuit. This actually does two things. It keeps the antenna away from the highly active collector and turns the coil into an auto-transformer where the energy from the 8 turns is passed to a single turn. This effectively increases the current into the antenna. And that is exactly what we want.
The range is not as far but the stability is better. The frequency will not drift as much when the bug is held. As the tap is taken towards the collector, the output increase but the stability deceases.

2-TRANSISTOR CIRCUIT

The next progressive step is to add a transistor to give the electret microphone more sensitivity. The electret microphone contains a Field Effect Transistor and you can consider it to be a stage of amplification. That's why the electret microphone has a very good output.
A further stage of amplification will give the bug extremely good sensitivity and you will be able to pick up the sound of a pin dropping on a wooden floor.
Many of the 1 transistor circuits over-drive the microphone and this will create a noise like bacon and eggs frying. The microphone's used by Talking Electronics require a load resistor of 47k for a 6v supply and 22k for a 3v supply. The voltage across the microphone is about 300mV to 600mV.
Only a very simple self-biasing common-emitter stage is needed. This will give a gain of approx 70 for a 3v supply. The circuit below shows this audio amplifier, added to the previous transmitter circuit. This circuit is the best design using 2 transistors on a 3v supply. The circuit takes about 7mA and produces a range of about 200 - 400metres.

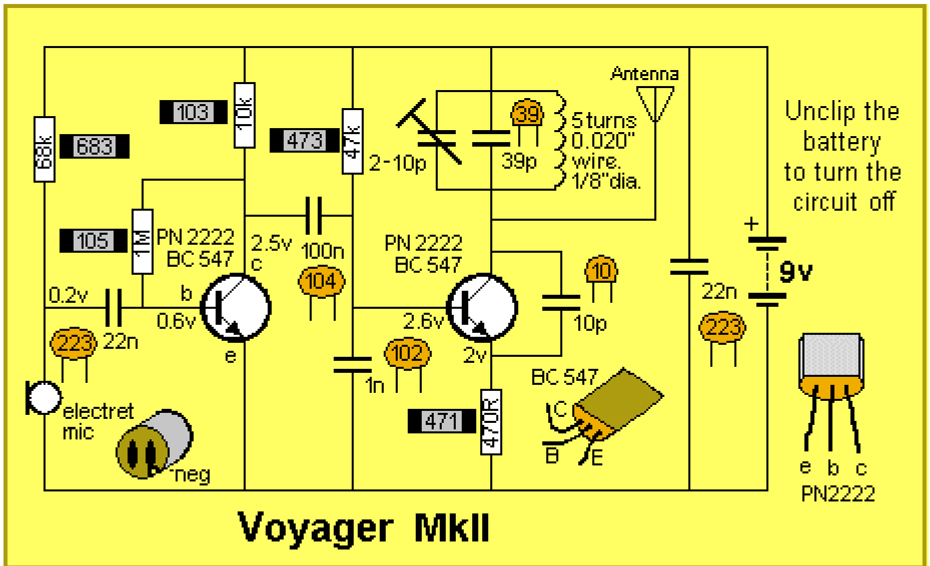


Five points to note in the circuit above:
1. The tank circuit has a fixed 39p and is adjusted by a 2-10p trimmer. The coil is stretched to get the desired position on the band and the trimmer fine tunes the location.
2. The microphone coupling is a 22n ceramic. This value is sufficient as its capacitive reactance at 3-4kHz is about 4k and the input to the audio stage is fairly high, as noted by the 1M on the base.
3. The 1u between the audio stage and oscillator is needed as the base has a lower impedance as noted by the 47k base-bias resistor.
4. The 22n across the power rails is needed to keep the rails "tight." Its impedance at 100MHz is much less than one ohm and it improves the performance of the oscillator enormously.
5. The coil in the tank circuit is 5 turns of enameled wire with air core. The secret to long range is high activity in the oscillator stage. The tank circuit (made up of the coil and capacitors across it) will produce a voltage higher than the supply voltage due to the effect known as "collapsing magnetic field" and this occurs when the coil collapses and passes its reverse voltage to the capacitor. The antenna is also connected to this point and it receives this high waveform and

passes the energy to the atmosphere as electromagnetic radiation.
When the circuit is tightly constructed on a PC board, the frequency will not drift very much if the antenna is touched.

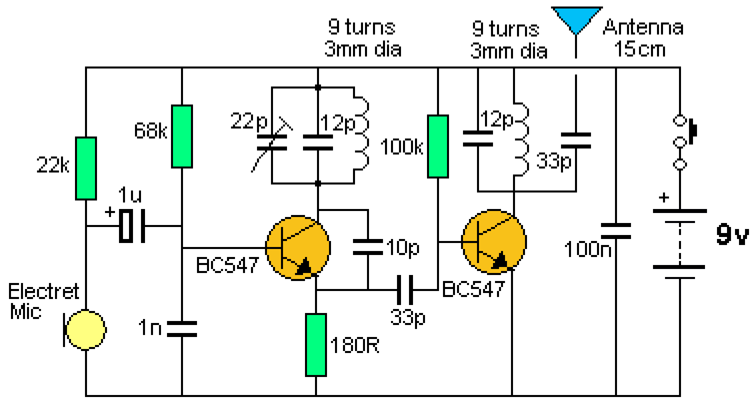
THE VOYAGER

The only way to get a higher output from two transistors is to increase the supply voltage.
The following circuit is available from Talking Electronics as a surface-mount kit, with some components through-hole.
The project is called THE VOYAGER.



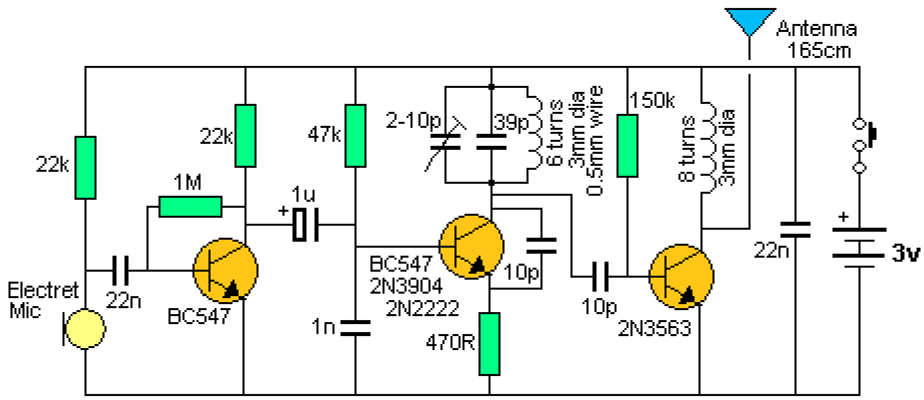
All the elements of good design have been achieved in this project. The circuit has a slightly higher output than the 3v circuit above, but most of the voltage is lost across the emitter resistor and not converted to RF. The main advantage of this design is being able to connect to a 9v battery. In a technical sense, about half the energy is wasted as the stages actually require about 4v - 5v for maximum output.

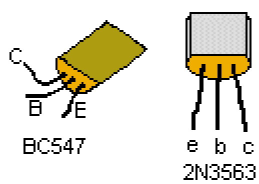
HAND-HELD MICROPHONE



This circuit is suitable for a hand-held microphone. It does not have an audio stage but that makes it ideal as a microphone, to prevent feedback. The output has a buffer stage to keep the oscillator away from the antenna. This gives the project the greatest amount of stability -rather than the highest sensitivity.

INCREASING THE RANGE

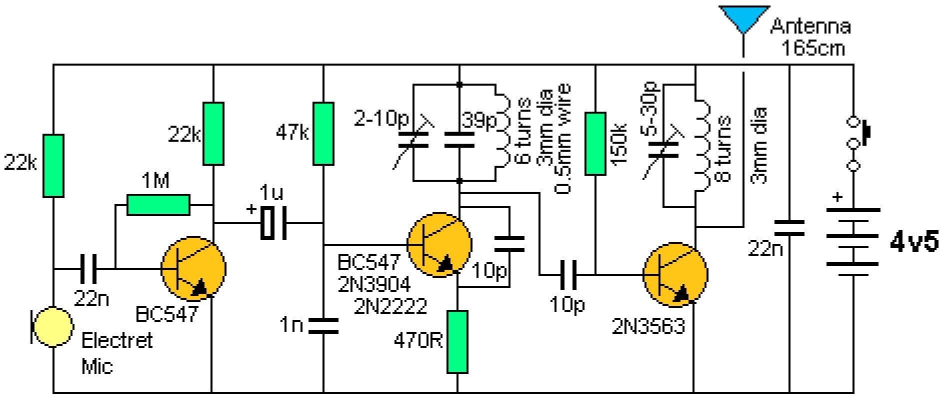




To increase the range, the output must be increased. This can be done by using an RF transistor and adding an inductor. This effectively converts more of the current taken by the circuit (from the battery) into RF output. The output is classified as an untuned circuit. A BC547 transistor is not suitable in this location as it does not amplify successfully at 100MHz. It is best to use an RF transistor such as 2N3563.

MORE RANGE

More output can be obtained by increasing the supply voltage and adding a capacitor across the inductor in the output stage to create a tuned output.
The 5-30p must be adjusted each time the frequency of the bug is changed. This is best done with a field strength meter. See Talking Electronics Field Strength Meter project.

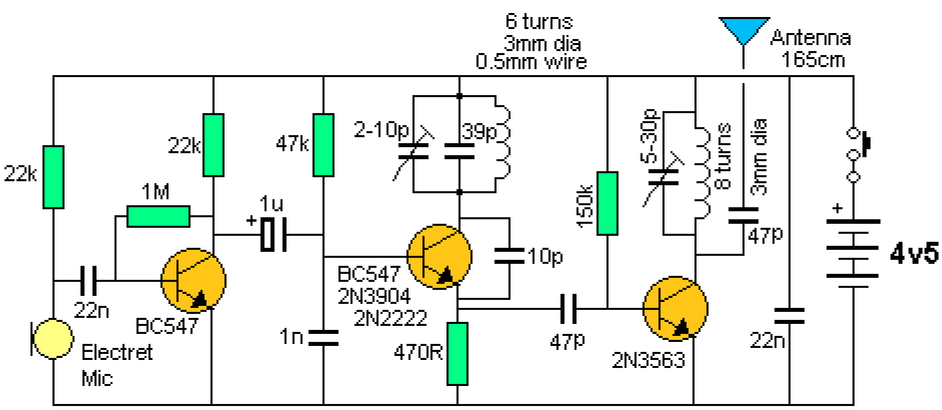


A tuned output stage delivers more output

The 2N3563 is capable of passing 15mA in the buffer stage and about 30% is delivered as RF. This makes the transmitter capable of delivering about 22mW.

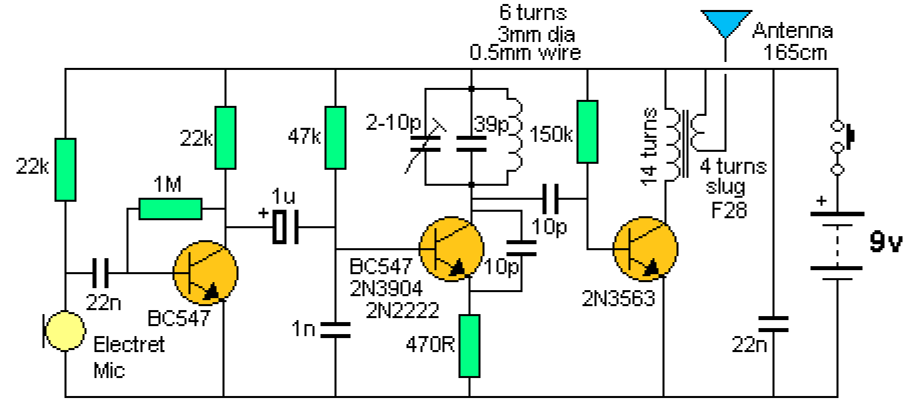
EMITTER TAP

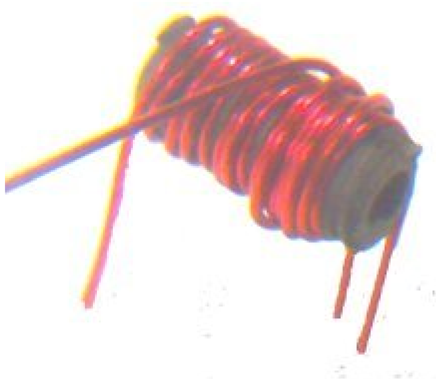
The following circuit taps the emitter of the oscillator stage. The collector or the emitter can be tapped to produce about the same results, however tapping the emitter "loads" the oscillator less. The 47p capacitor is adjusted to "pick-off" the desired amount of energy from the oscillator stage. It can be reduced to 22p or 10p.



Tapping the emitter of the oscillator transistor

GOING FURTHER



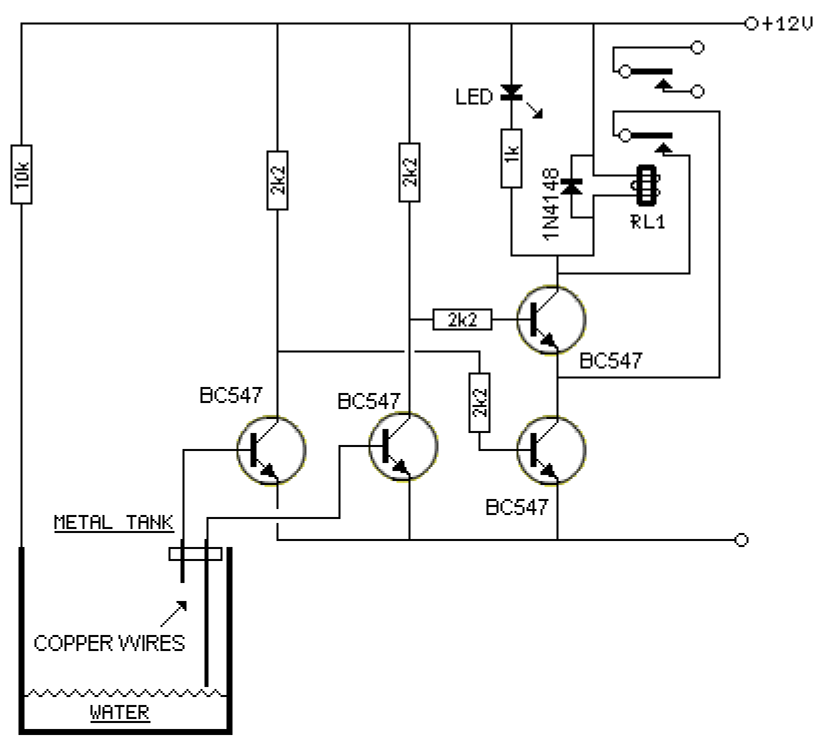


THE RF TRANSFORMER

The next stage to improve the output, matches the impedance of the output stage to the impedance of the antenna.
The impedance of the output stage is about 1k to 5k, and the impedance of the antenna is about 50 ohms.
This creates an enormous matching problem but one effective way is with an RF transformer.
An RF transformer is simply a transformer that operates at high frequency. It can be air cored or ferrite cored. The type of ferrite needed for 100MHz is F28. The circuit above uses a small ferrite slug 2.6mm dia x 6mm long, F28 material.
To create an output transformer for the circuit above, wind 11 turns onto the slug and 4 turns over the 11 turns. The ferrite core will do two things. Firstly it will pass a high amount of energy from the primary winding to the antenna and secondly it will prevent harmonics passing to the antenna.
The transformer approximately doubles the output power of the transmitter.

WATER LEVEL DETECTOR

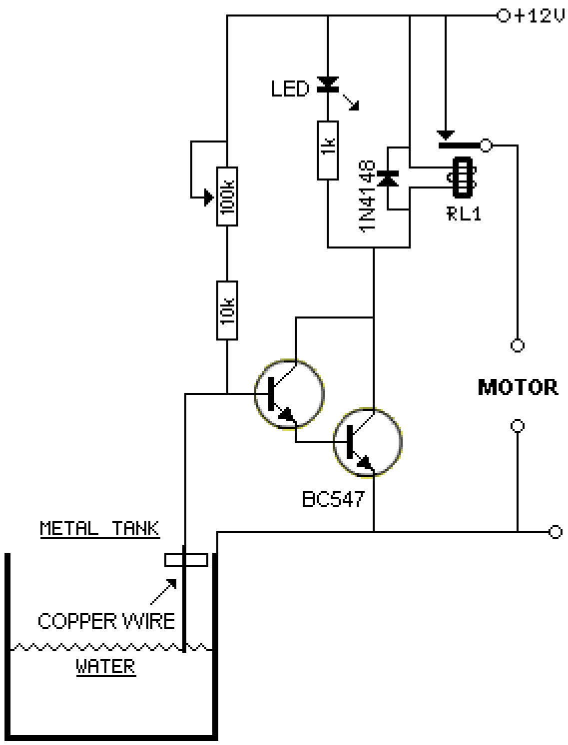
This circuit can be used to automatically keep the header tank filled. It uses a double-pole relay.



CIRCUIT 2

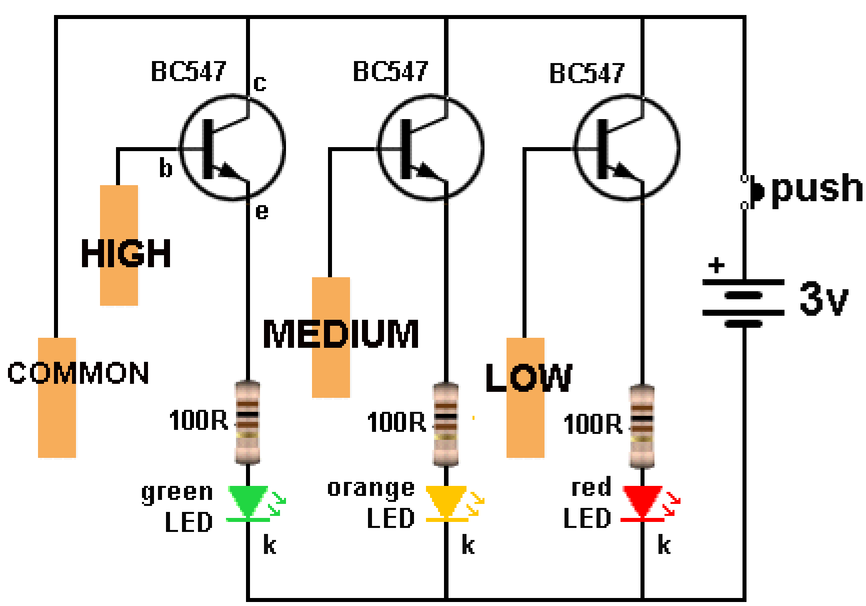
The circuit below is the simplest design and consumes almost zero current when the tank is full. When the water is LOW, the circuit is turned ON via the 100k pot and 10k resistor.
When the water reaches the copper wire, the voltage on the base of the first transistor reduces and the current into the Darlington arrangement is too small to keep the relay energised and the motor turns

OFF.
As the water-level drops, the current into the Darlington pair increases and a point is reached when the relay pulls-in again.



CIRCUIT 3

This simple circuit will show the water level in a tank.
It has a HIGH, MEDIUM and LOW levels and as the water touches the pads, the LEDs start to illuminate. This produces a range of levels to let you know exactly the level of the water.
The sensor pads can be cut from a tin-can or you can use the lid of a tin.
The main sensor is placed at the bottom of the water so the low-level LED will let you know the tank is almost empty.

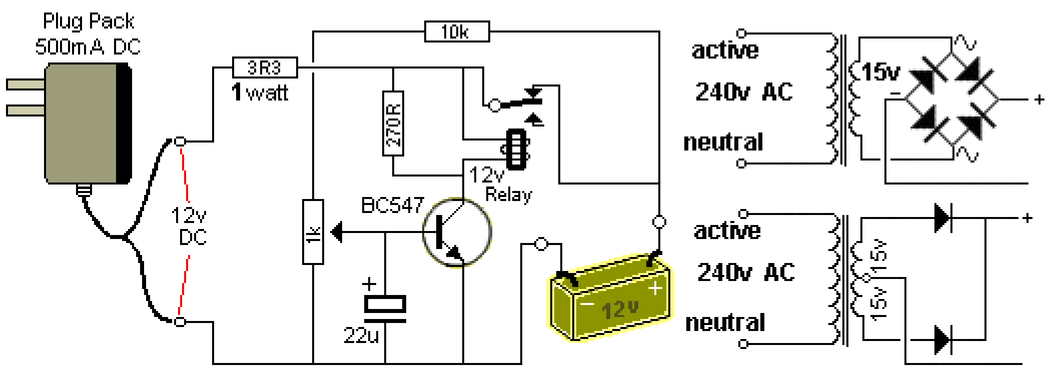


The circuit has been drawn to show the transistors are placed on the top of the tank with wires going to each of the sensor pads. The LEDs and resistors are mounted on a wall in your house with the 3v supply and a push-switch.
You will need a 4-wire connection between the two units and this can be 4-core telephone cable.
The transistors are wired as emitter-followers and this saves 4 resistors (base-bias resistors). It also allows the LEDs to come on slowly as the water rises so you get a wide indication of the water level.
You can add more sensors if required. Simply repeat the circuit above for 3 more levels.

Any NPN transistor can be used and any value resistor between 100 ohms and 330 ohms can be used and the voltage can be increased to 6v if you are using a high-value resistor.
The circuit only takes current when the switch is pressed but it can be left ON all the time to let you know the water level, if needed.
You don't need a circuit board. Simply hammer a few nails into a length of wood to hold the sensors and connect the transistors to the nails by soldering.
Make sure the sensor pads are away form the wood and don't hold any water when the level goes down as the circuit is so sensitive that the LEDs will not go out.

BATTERY CHARGER - world's simplest automatic charger

This is the world's simplest automatic battery charger.
It consists of 6 components, when connected to a 12v DC plug pack. The plug pack must produce more than 15v on no-load (which most plug packs do.) An alternative 15v transformer and a centre-tapped transformer is also shown. A centre-tapped transformer is referred to as: 15v-CT-15v or 15-0-15
The relay and transistor are not critical as the 1k pot is adjusted so the relay drops-out at 13.7v.
To improve the "pull-in" and "drop-out" voltages, the 10k can be replaced with a 12v zener. The zener can be made up of two 6v zeners or any combination in series and include ordinary diodes (drop 0.6v).
The plug pack can be 300mA, 500mA or 1A and its current rating will depend on the size of the 12v battery you are charging.
For a 1.2AH gel cell, the charging current should be 100mA. However, this charger is designed to keep the battery topped-up and it will deliver current in such short bursts, that the charging current is not important. This applies if you are keeping the battery connected while it is being used. In this case the charger will add to the output and deliver some current to the load while charging the battery. If you are charging a flat cell (flat 12v battery - a discharged 12v battery), the current should not be more than 100mA.
For a 7AH battery, the current can be 500mA. And for a larger battery, the current can be 1Amp.



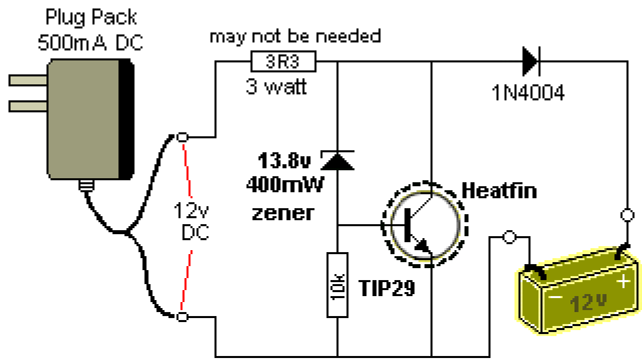
Most 12v Plug Packs produce 15v to 16v on NO-LOAD and we are using this feature to charge the battery. We are also using the poor regulation of the plug pack to charge the battery without the plug pack overheating.

SETTING UP

Connect the charger to a battery and place a digital meter across the battery. Adjust the 1k pot so the relay drops out as soon as the voltage rises to 13.7v.
Place a 100R 2watt resistor across the battery and watch the voltage drop.
The charger should turn on when the voltage drops to about 12.5v. This voltage is not extremely critical. It happens to be the "hysteresis" of the circuit and is determined by the value of the load in the collector of the transistor.
The 22u stops the relay "squealing" or "hunting" when a load is connected to the battery and the charger is charging. As the battery voltage rises, the charging current reduces and just before the relay drops out, it squeals as the voltage rises and falls due to the action of the relay. The 22u prevents this "chattering".
To increase the Hysteresis: In other words, decrease the voltage where the circuit cuts-in, add a 270R across the coil of the relay. This will increase the current required by the transistor to activate the relay and thus increase the gap between the two activation points. The pull-in point on the pot will be higher and you will have re-adjust the pot, but the drop-out point will be the same and thus the gap will be wider.
In our circuit, the cut-in voltage was 11.5v with a 270R across the relay.
Note: No diode is needed across the relay because the transistor is never fully turned off and no back EMF (spike) is produced by the relay.

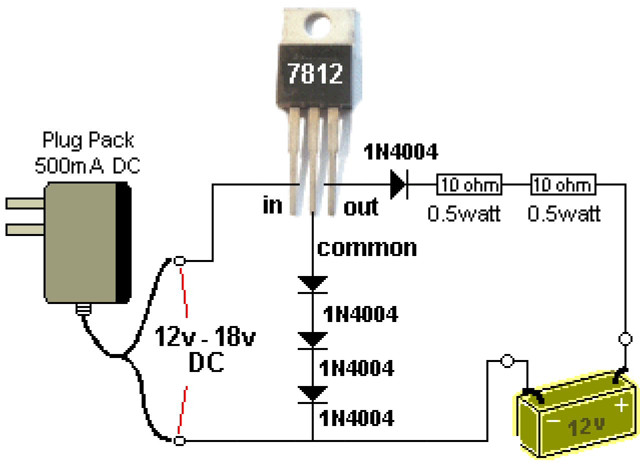
AUTOMATIC BATTERY CHARGER - trickle charger

This circuit will automatically keep a battery fully charged with the charge-current reducing when the battery voltage reaches 13.8v. The battery can be used at any time and the charger will maintain full charge.



The transistor acts like a POWER ZENER (with the 13.8v zener on the base) and the supply rail does not rise above 13.8v + 0.6v = 14.4v. The 1N4004 removes the 0.6v to deliver 13.8v to the battery.
If the plug pack is replaced with a supply capable of delivering a voltage higher than 16v (on no-load), the 3R3 (3watt) resistor will be needed. The transistor simply removes the charging current from the battery and wastes it as heat.

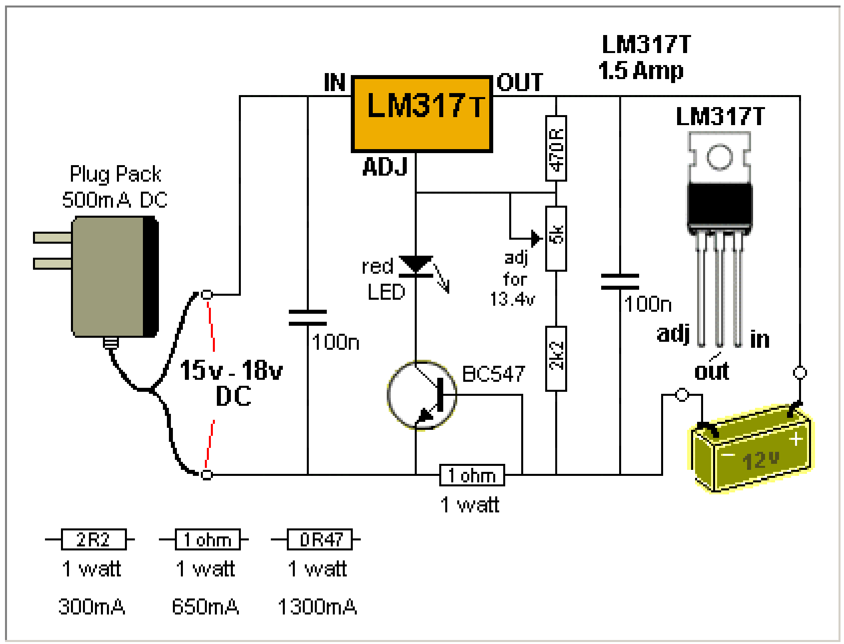
BATTERY CHARGER MkII - a very simple design to keep a battery "topped up."



This is a very simple battery charger to keep a battery "nearly fully charged."
It consists of 7 components, when connected to a 12v - 18v DC plug pack. The plug pack must produce more than 15v on no-load (which most 12v plug packs do.)
For a 1.2AH gel cell, up to a 45Ahr car or boat battery, this charger will keep the battery topped-up and can be connected for many months as the battery will not lose water due to "gassing."
The output voltage is 13.2v and this is just enough to keep the battery from discharging, but will take a very long time to charge a battery, if it is flat because a battery produces a "floating charge" of about 13.6v when it is being charged (at a reasonable current) and this charger is only designed to deliver a very small current.
There is a slight difference between a "old-fashioned" car battery (commonly called "an accumulator") and a sealed battery called a Gel Cell. The composition of the plates of a gel cell is such that the battery does not begin to "gas" until a high voltage is reached. That is why it can be totally closed and only has rubber bungs that "pop" if gas at high pressure develops due to gross over-charging. That's why the charging voltage must not be too high and when the battery is fully charged, the charging current must drop to a very low level.

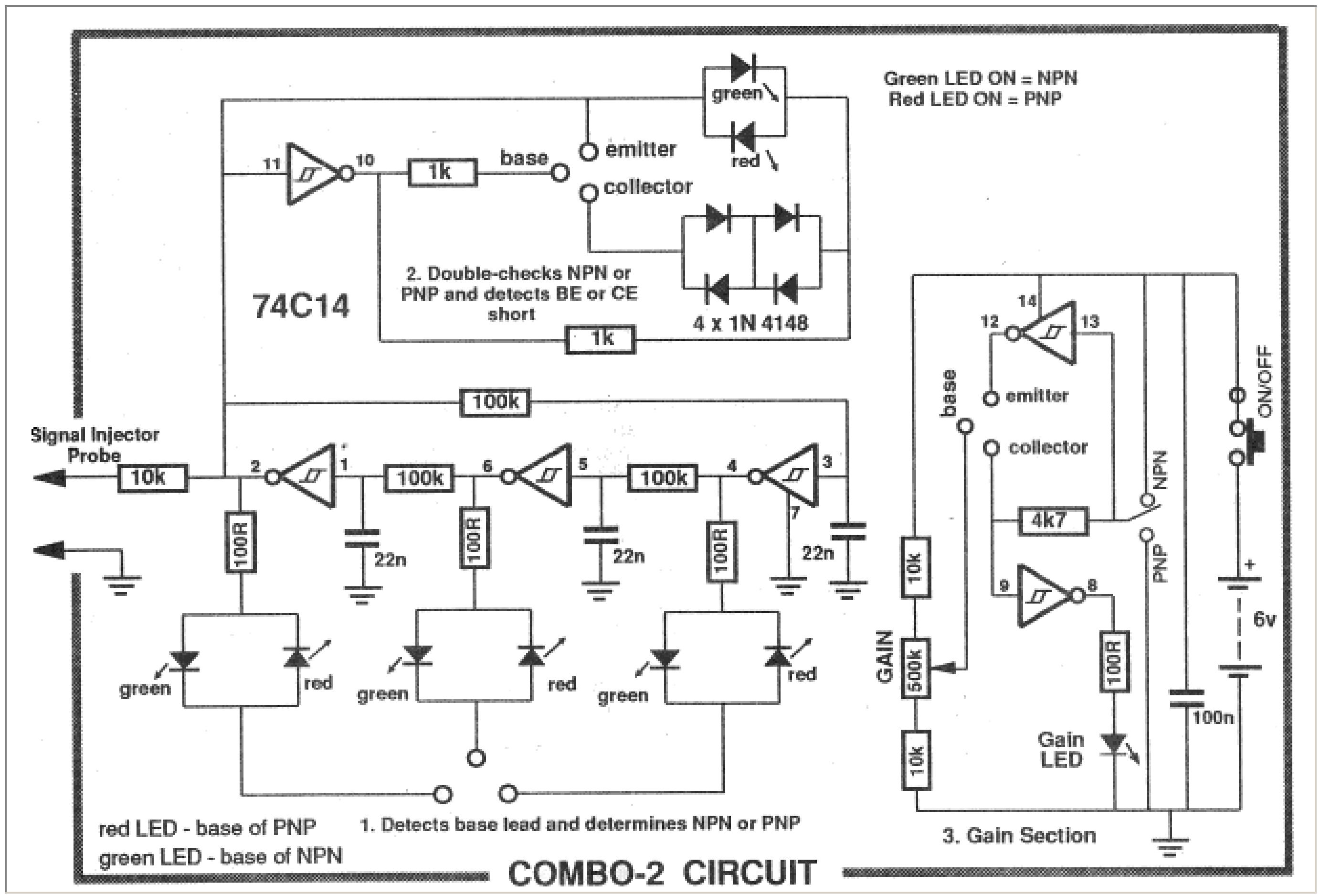
GELL CELL BATTERY CHARGER

This circuit will charge gell cell batteries at 300mA or 650mA or 1.3A, depending on the CURRENT SENSING resistor in the 0v rail. Adjust the 5k pot for 13.4v out and when the battery voltage reaches this level, the current will drop to a few milliamps. The plug pack will need to be upgraded for the 650mA or 1.3A charge-current. The red LED indicates charging and as the battery voltage rises, the current-flow decreases. The maximum is shown below and when it drops about 5%, the LED turns off and the current gradually drops to almost zero.



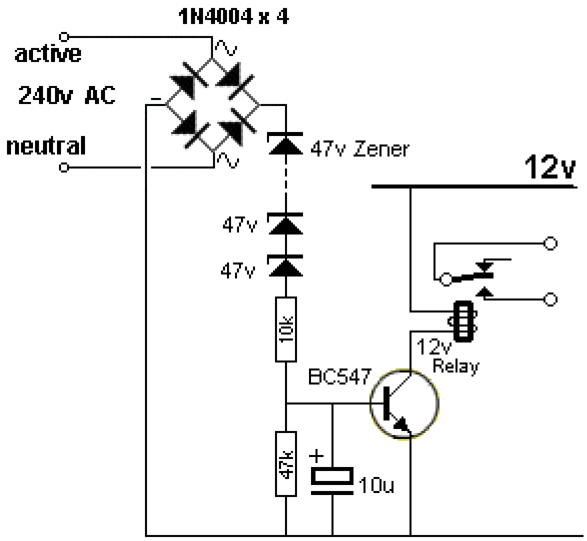
TRANSISTOR TESTER   COMBO-2

This circuit uses an IC but it has been placed in this eBook as it is a transistor tester.
The circuit uses a single IC to perform 3 tests:
Test 1: Place the transistor in any orientation into the three terminals of circuit 1 (below, left) and a red LED will detect the base of a PNP transistor an a green LED will indicate the base of an NPN transistor.
Test 2: You now now the base lead and the type of transistor. Place the transistor in Test 2 circuit (top circuit) and when you have fitted the collector and emitter leads correctly (maybe have to swap leads), the red or green LED will come on to prove you have fitted the transistor correctly.
Test 3: The transistor can now be fitted in the GAIN SECTION. Select PNP or NPN and turn the pot until the LED illuminates. The value of gain is marked on the PCB that comes with the kit. The kit has ezy clips that clip onto the leads of the transistor to make it easy to use the project.
The project also has a probe at one end of the board that produces a square wave - suitable for all sorts of audio testing and some digital testing.
Project cost: $22.00 from Talking Electronics.

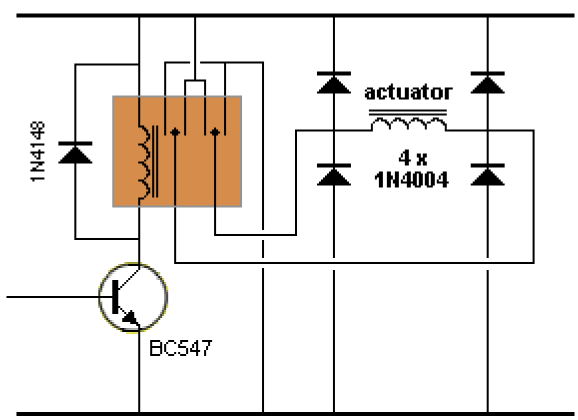


LOW MAINS DROPOUT

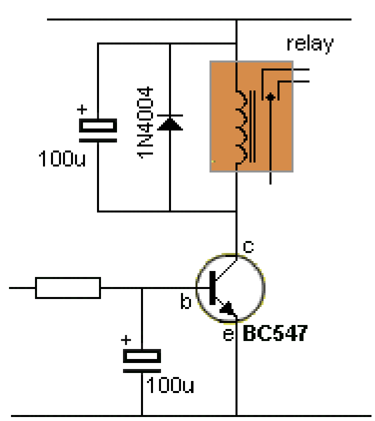
This circuit will turn off a device if the main drops by a say 15v. The actual voltage is adjustable. The first thing to remember is this: The circuit detects the PEAK voltage and this is the voltage of the zener diodes.
For 240v mains, the peak is 338v.
For a voltage drop of about 12v(RMS), the zener diodes need to have a combined voltage of 320v (you will need 6 x 47v + 1 x 20v + 1 x 18v).
The 10k resistor will have about 18v across it and the current will be nearly 2mA. The wattage will be 36mW.
For a voltage drop of about 27v(RMS), you will need zeners for a total of 300v by using 6 x 47v + 1 x 18v. The voltage across the 10k resistor will be 38v and the current will be nearly 4mA. The wattage dissipated by the 10k resistor will be 150mW.
The 10u prevents very sharp dips or drops from activating the circuit.
As the voltage drops, this drop in voltage will be passed directly to the top of the 10k resistor and as the voltage drops, the current into the base of the transistor will reduce. This current is amplified by the transistor and when it is not sufficient to keep the relay activated, it will drop-out.



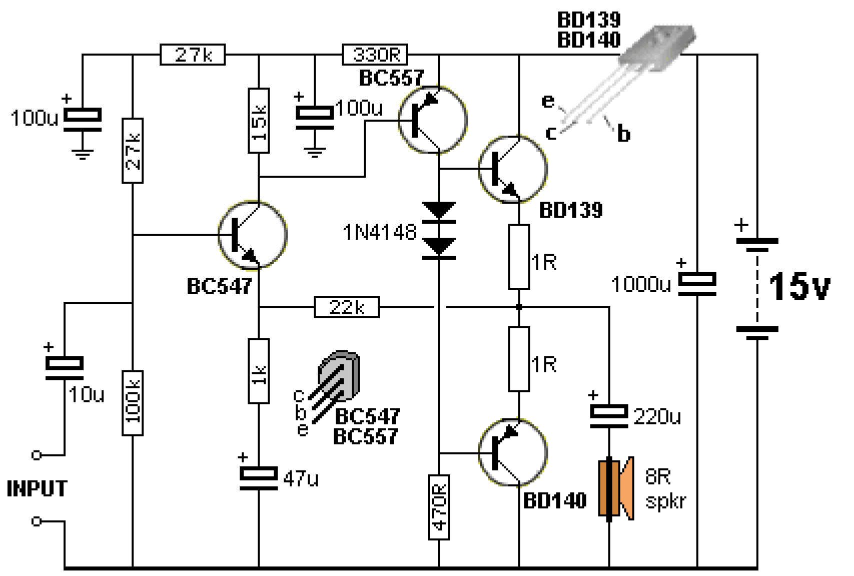
PROTECTING THE CONTACTS OF A RELAY:
The contacts of a relay can be protected from the damaging effects of reversing an actuator. The circuit shows a double-pole double-throw relay driving an actuator. The 4 "bridge diodes" around the actuator "squelch" the back-emf from damaging the contacts.



REDUCING RELAY CHATTER:
To reduce the relay clicking or chattering during the activation of the relay driver transistor, an electrolytic can be placed between the base and 0v rail. In addition an electro can be placed across the relay if there is a possibility of the supply voltage glitching or temporally failing.

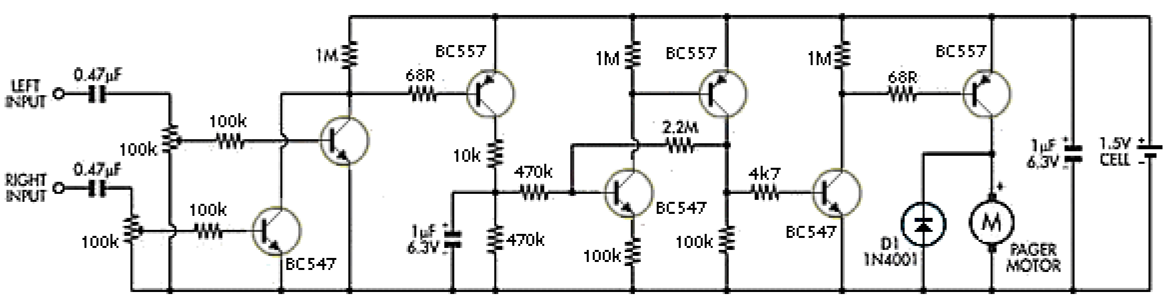


4 TRANSISTOR AMPLIFIER:
This circuit is fully documented in [The Transistor Amplifier] as Fig 105.



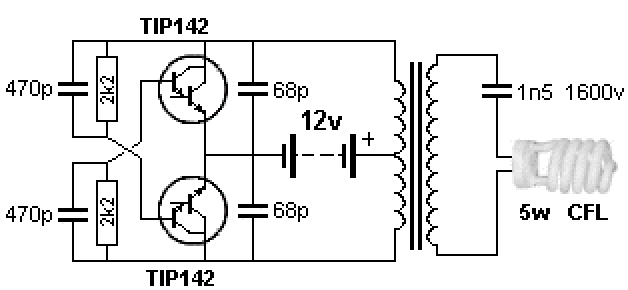
Vibrating VU Indicator

This circuit can be used to monitor the output of a stereo to warn when the level is too high. The output is a pager motor and will vibrate so you don't have to keep watching VU levels. The first two transistors are connected so an overload in either channel will trigger the pager motor.

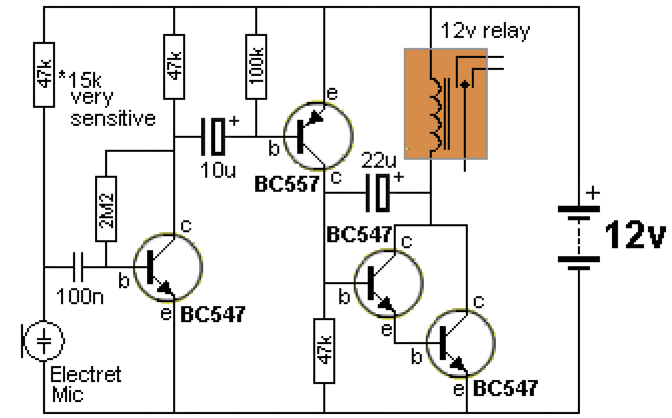


No power switch is needed as all transistors are turned OFF when no audio is being detected.

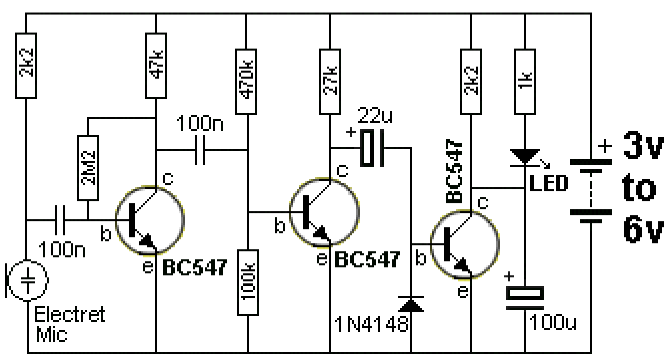
CFL DRIVER
This circuit will drive a 5watt Compact Fluorescent Lamp from 12v:



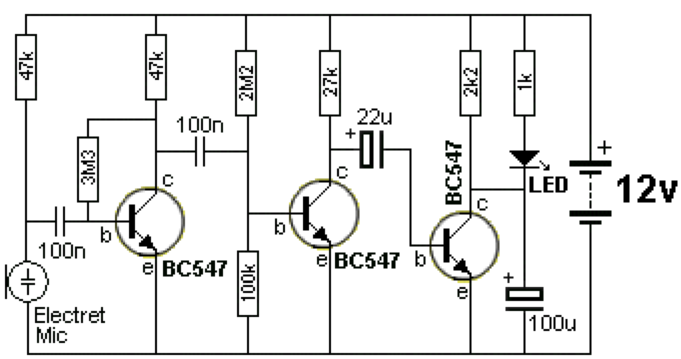
VOX
These circuits detect audio and operate a relay or produce an output pulse. See full details in: [The Transistor Amplifier eBook] - under VOX



SENSITIVE VOX CIRCUIT

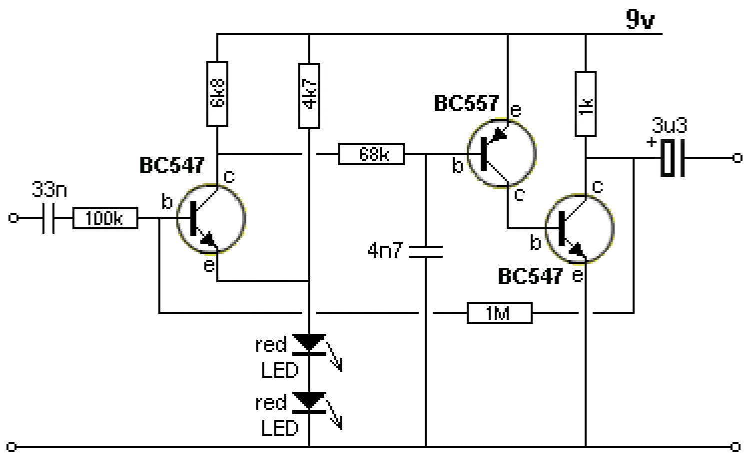


3v to 6v VOX CIRCUIT



12v VOX CIRCUIT

OP-AMP WITH 3 TRANSISTORS:
This circuit shows how a simple operational amplifier can be made with 3 transistors.

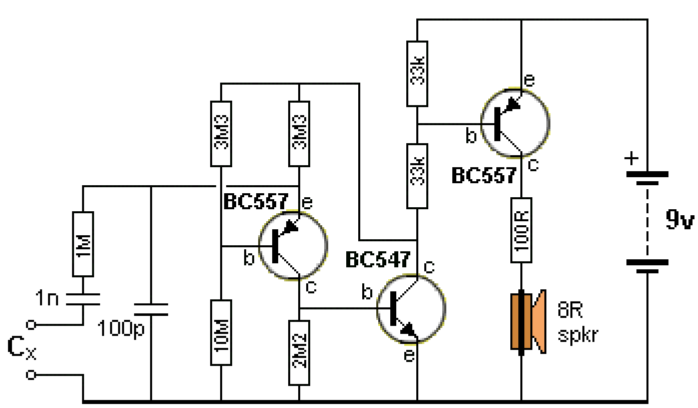


3-TRANSISTOR OP-AMP

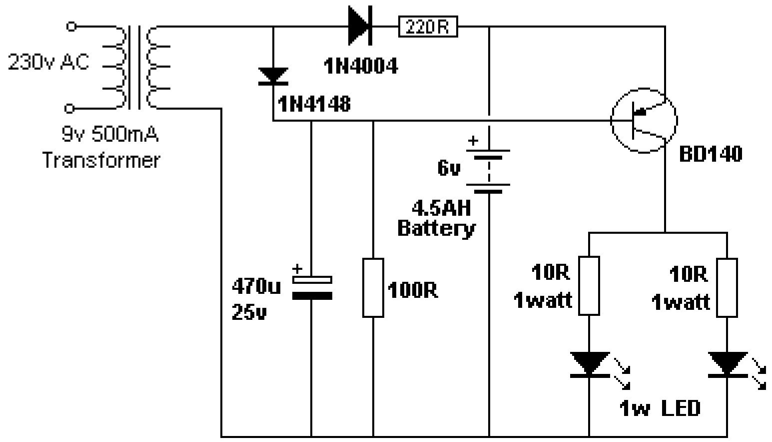
It is really an AC-coupled single-ended class A amp, with an open-loop gain of about 5,000, but as a demonstration-circuit, you can treat it as a simple op-amp. The output is biased at approximately one-half the supply voltage using the combined voltage drops across the two LEDs, the emitter-base voltage of the input transistor and the 1v drop across 1M feedback resistor. The 68k and 4n7 form a compensation network that prevents the circuit from oscillating.

You can configure this op amp as an active filter or as an oscillator. It drives a load of 1kΩ. The square-wave response is good at 10kHz, and the output reduces by 3dB at 50kHz.

CAPACITOR TESTER
Circuit designed by: Charles Wenzel charles@wenzel.com
This circuit will test very small capacitors. The tone from the speaker will change when a capacitor is placed across the test-points "Cx."
The operation of the circuit is explained in our eBook: The Transistor Amplifier (high impedance circuit).



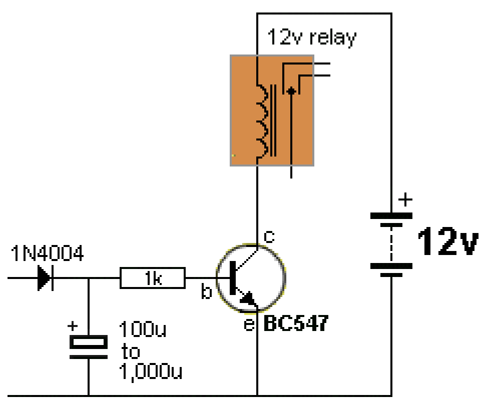
High bright LED Emergency Light



This circuit will illuminate two 1watt High-bright LEDs when the power fails. The charging current is about 20-30mA. It will take about 7 days to charge the battery and this will allow illumination for 5 hours, once per week.
A charging current more than 50mA will gradually "dry-out" the battery and shorten its life.
If the project is used more than 5 hours per week, the charging current can be increased.
The 220R charging resistor can be reduced to 150R or 100R (1watt).

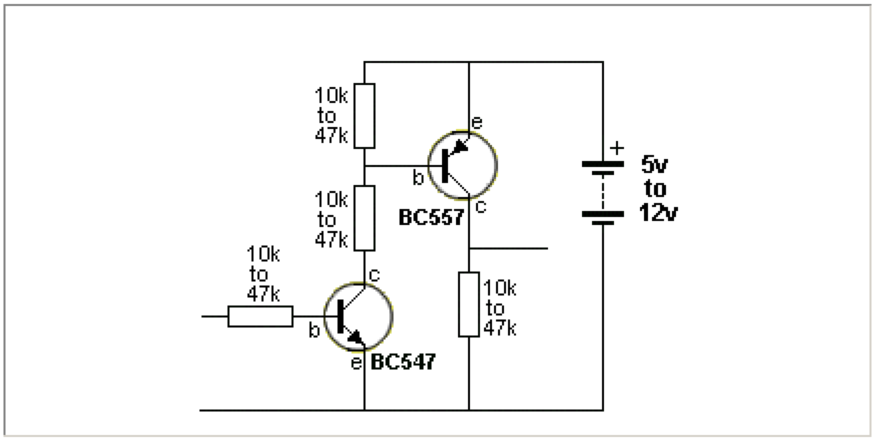
RELAY OFF DELAY

This circuit turns ON a relay when the input is above 2v and the relay turns OFF after 2 seconds when the signal is removed. The OFF delay can be increased or decreased.

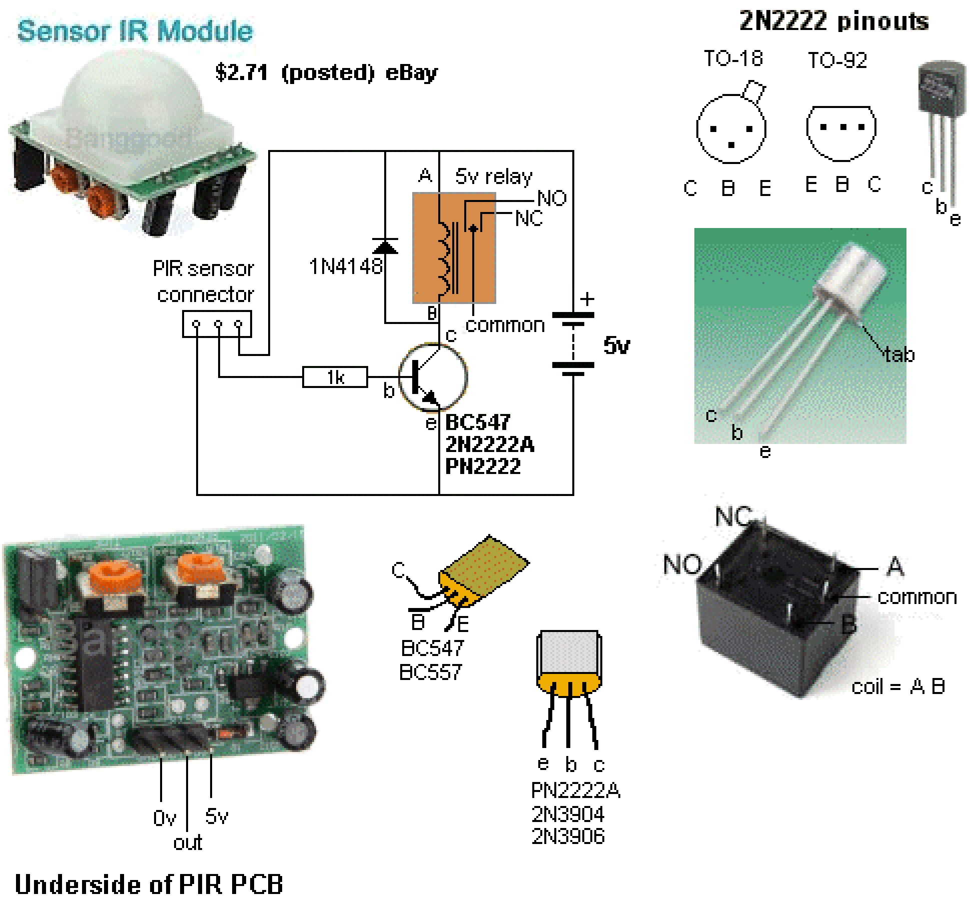


AMPLIFYING A DIGITAL SIGNAL

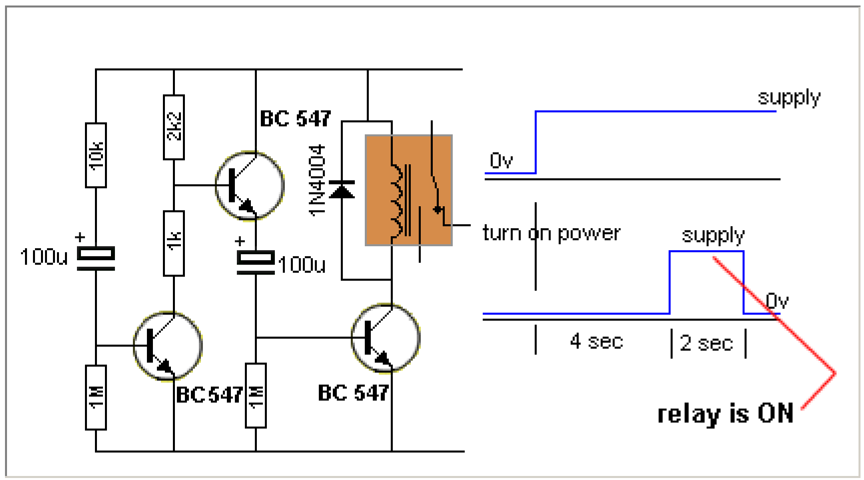
A Digital signal is only detected as a HIGH or LOW. However if the digital signal does not have sufficient amplitude, it may not be detected AT ALL.
This circuit detects a low amplitude signal and produces a high-amplitude signal.



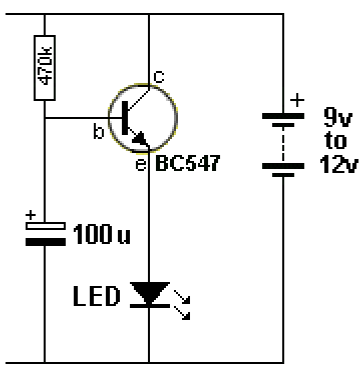
PIR DETECTOR
(see also [LED Strip Passage Light](#))
This circuit detects movement and operates a relay. The PIR module has "Sensitivity" and "Time Delay" pots. They can be purchased on eBay for $2.71 including postage!



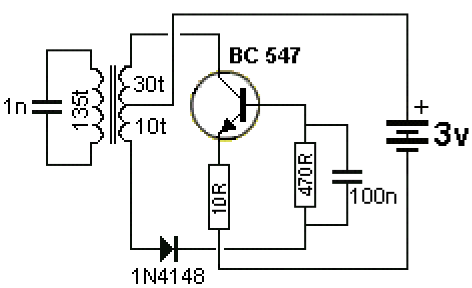
DELAY before Turn On then turns OFF
This circuit turns ON the relay 4 seconds after the power is applied and then turns it OFF after 2 seconds.
This is a request from a reader.
You will need to change the component values to suit your own timing.

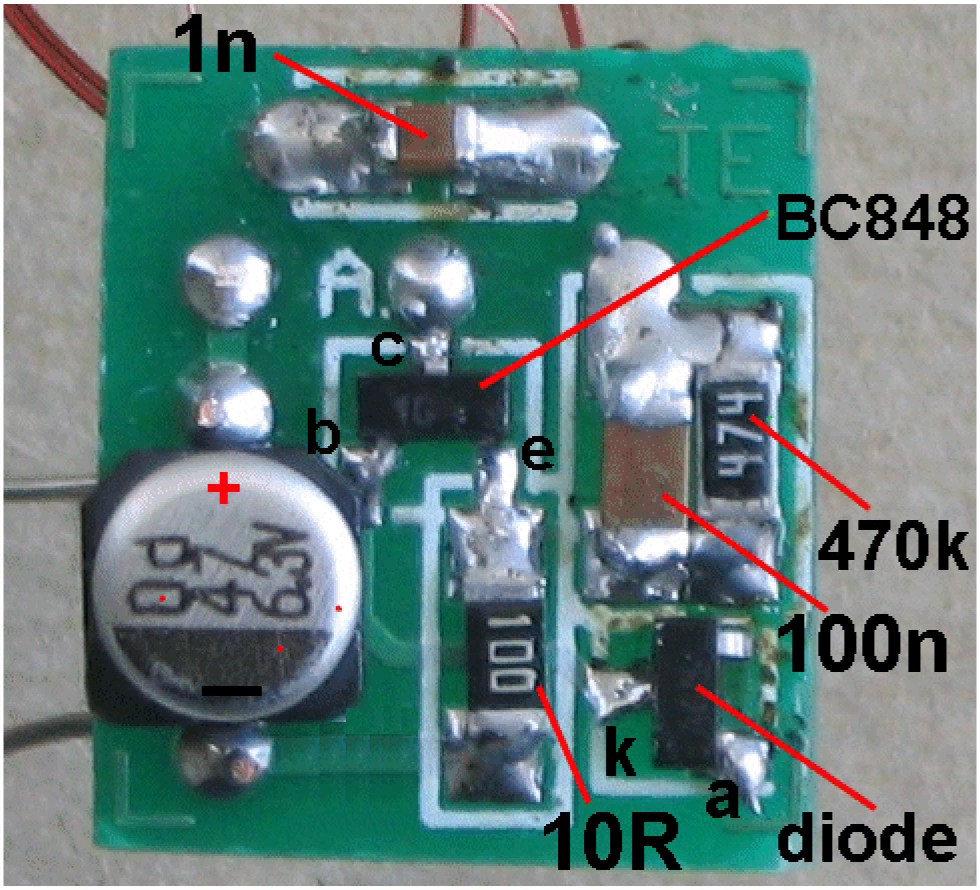


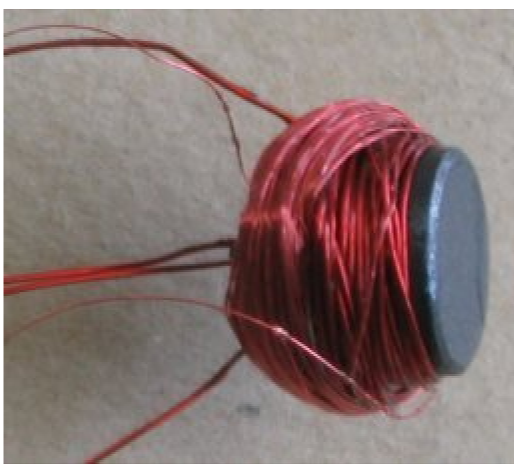
10 SECOND DELAY
This clever circuit turns on the LED 10 seconds after the power has been switched ON. The secret to its performance is the gain of the transistor.
With a gain of 200, the transistor will appear as a 470/200 = 2k3 resistor for the LED and for a 12v supply, this will create a current of 12-1.7 / 2300 = 4.4mA through the LED.
The 100u will take about 10 seconds to charge to a point where the base is 1.7v + 0.6v = 2.3v above the 0v rail. When the electro charges to this voltage, the LED starts to come on.
The transistor effectively becomes a 2k3 resistor and that's why no additional current-limiting resistor for the LED is needed. The transistor is the current-limiting device!



FERRET FINDER:
This circuit produces a beep-beep-beep at approx 190kHz on a **Long Wave Band** radio. The transformer (coil) is wound on 10mm dia ferrite rod 10mm long. The secondary winding is 0.25mm wire. The 135t is 0.01mm wire.



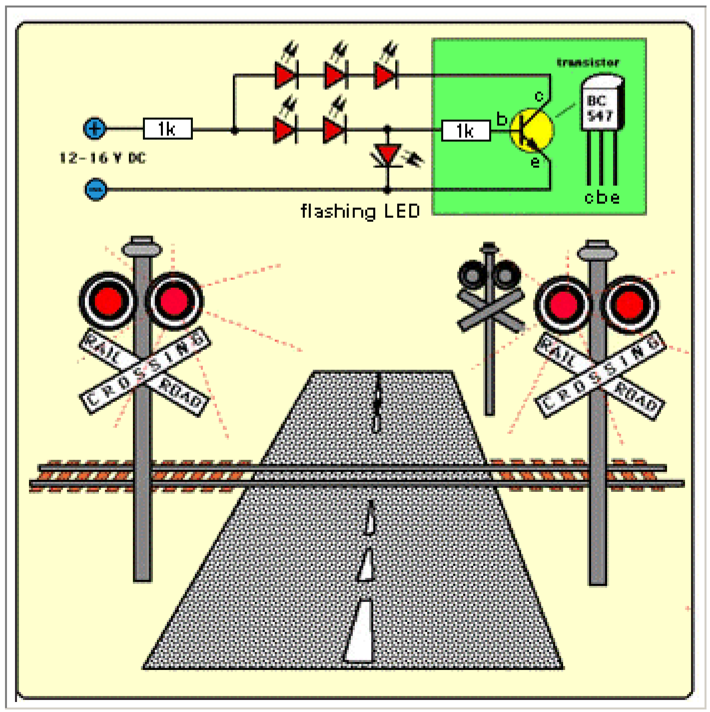




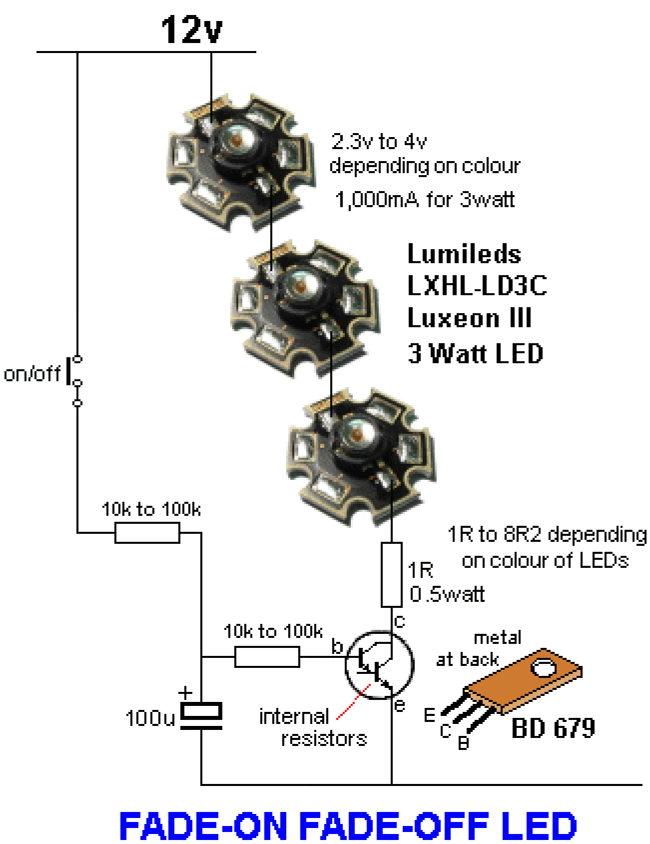
The PC board is 16mm x 14mm.
The secret to the circuit working is the "transformer." The ferrite must be very short so the flux produced by the circuit saturates the core and the excess is passed to the surroundings.

A kit for the Ferret Finder is available from talking electronics for $5.00 plus postage.

FLASHING LIGHTS FOR MODEL RAILWAY CROSSING:
A flashing LED is used to create the timing for the flash-rate and the transistor provides the alternate flash for the second set of LEDs.



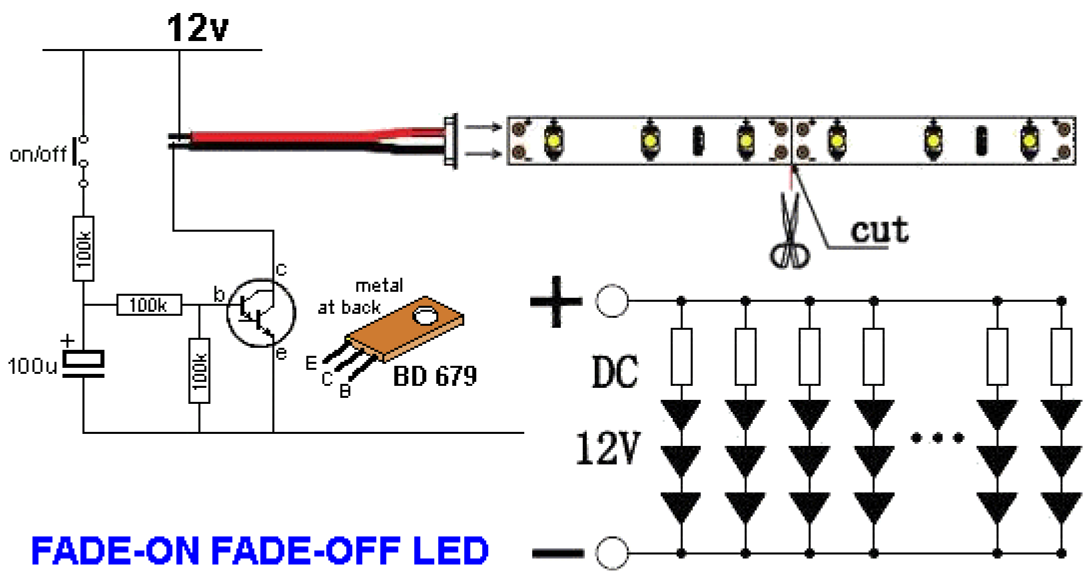
FADE-ON FADE-OFF LED
The LEDs in is circuit fade on when the power is applied and fade-off when switched off:



If you just want fade-ON and fade-OFF, this circuit is all you need. The Darlington transistor has internal resistors between the base and emitter of each transistor and these will reduce the input impedance of the transistor considerably. That's why you may have to use fairly low-value resistors on the delay section. Using two separate (normal) transistors will allow the resistor-values to be 100k.

You can also drive "rope lights."
These can be surface-mount LEDs or totally-sealed LEDs and generally have two wires connected to one end for the 12v supply.
Three LEDs are generally connected in series inside the "rope" with a dropper resistor and some

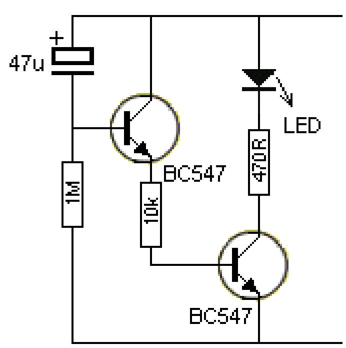
"ropes" can be cut after each set of three LEDs as shown in the diagram below:



Each set of three LEDs draws about 20mA so a rope of 24 LEDs takes about 160mA. Adjust the first two 100k resistors and 100u to set the fade-IN and fade-OUT feature.

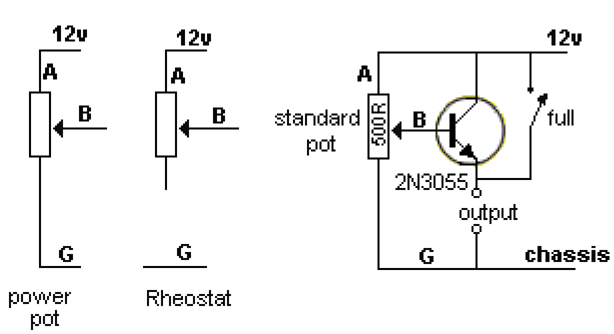
3-SECOND DELAY:

When this circuit is connected to a supply (from 3v to 12v), the LED turns on and gradually fades after about 3 seconds.



REPLACING A "POWER POT":

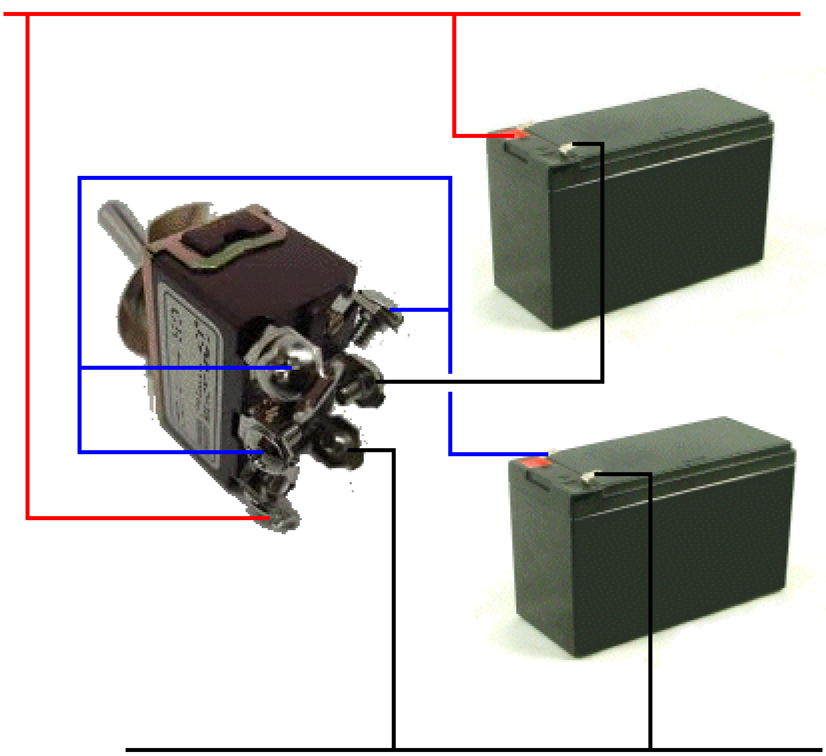
A **Power Potentiometer** (also called a rheostat) is a potentiometer with a rating of 1watt or more and these can be very expensive. A 10watt pot can cost as much as $25 to $35.
This type of pot can be replaced very cheaply by using an ordinary 500R pot and a power transistor.
The power pot generally "burns out" when it is at least resistance and this circuit replaces the pot with one slight exception.
The circuit does not deliver full rail voltage. The output is about 0.9v below rail voltage. A switch has been included to produce full rail output:



10 watt POWER POT

If the Power Pot is a rheostat, it will have two terminals. One terminal called "A" will go to rail voltage and the other terminal (the centre terminal - called the wiper) we will call "B," will go to the load.
Build the circuit above and take A and B to the same points as before and "G" goes to Ground or "earth" or "Chassis."

CHANGING 24v to 12v:
This circuit allows to you charge a 24v project from a 12v charger. It converts the two 12v batteries from series to parallel:

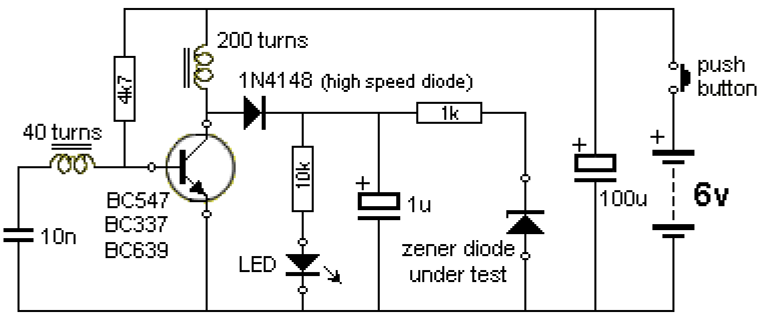


CHANGING 24v TO 12v

ZENER DIODE TESTER

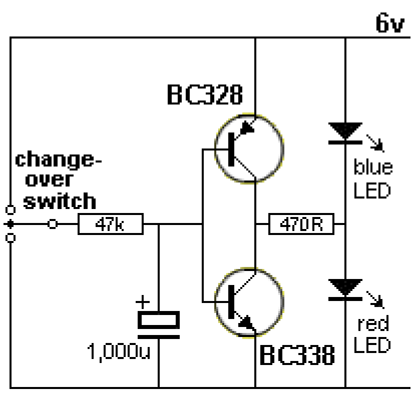
All diodes are Zener diodes. For instance a 1N4148 is a 120v zener diode as this is its reverse breakdown voltage.
And a zener diode can be used as an ordinary diode in a circuit with a voltage that is below the zener value.
For instance, 20v zener diodes can be used in a 12v power supply as the voltage never reaches 20v, and the zener characteristic is never reached.
Most diodes have a reverse breakdown voltage above 100v, while most zeners are below 70v. A 24v zener can be created by using two 12v zeners in series and a normal diode has a characteristic voltage of 0.7v. This can be used to increase

the voltage of a zener diode by 0.7v.
To tests a zener diode you need a power supply about 10v higher than the zener of the diode. Connect the zener across the supply with a 1k to 4k7 resistor and measure the voltage across the diode. If it measures less than 1v, reverse the zener.
If the reading is high or low in both directions, the zener is damaged.
Here is a zener diode tester. The circuit will test up to 56v zeners.



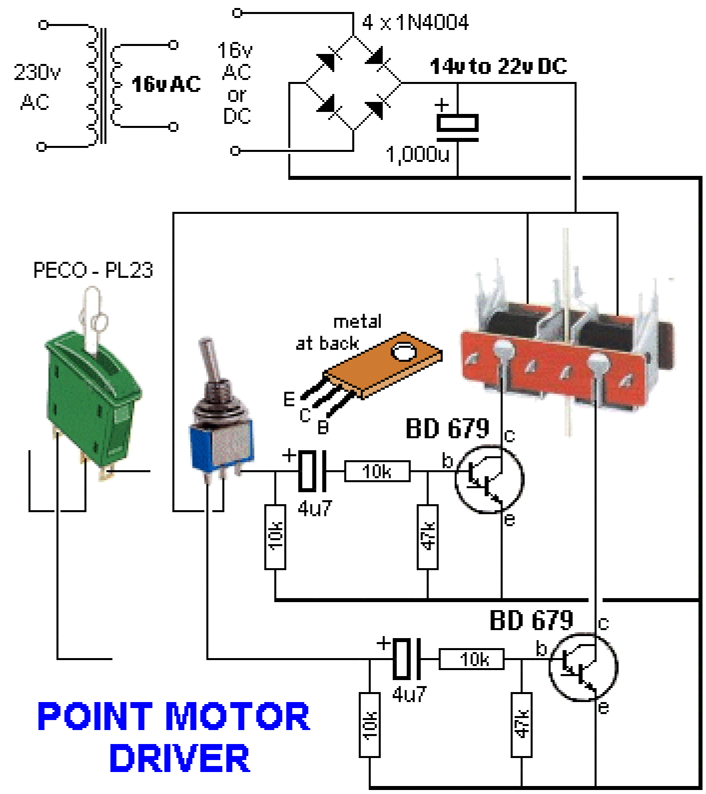
LED FADER

This circuit was requested by a theatrical group to slowly change the colour of a set of LEDs over a period of 1-2 seconds.

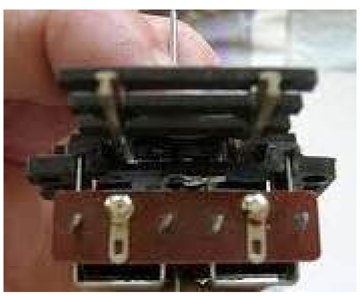


POINT MOTOR DRIVER

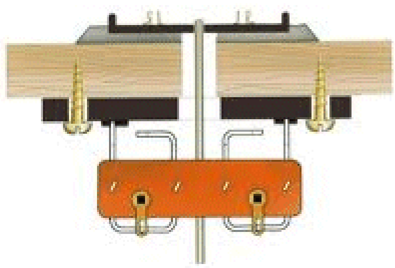
One of the first things (you will want) when expanding a model railway is a second loop or siding.
This needs a set of points and if they are distant from the operator, they will have to be electrically operated. There are a number of controllers on the market to change the points and some of them take a very high current. (You can get a low-current Point Motor).
The high current is needed because the actuating mechanism is very inefficient, but it must be applied for a very short period of time to prevent the point motor getting too hot.
Sometimes a normal switch is used to change the points and if the operator forgets use it correctly, the Point Motor will "burn-out" after a few seconds.
To prevent this from happening we have designed the following circuit. It operates the Point Motor for 5mS to 10mS (a very short time) and prevents any damage.
You can use a Peco switch (PL23 - about $10.00!!) or an ordinary toggle switch (change-over switch).
You can connect to either side of the Point Motor and both contacts of the other side go to 14v to 22v rail.



POINT MOTOR DRIVER



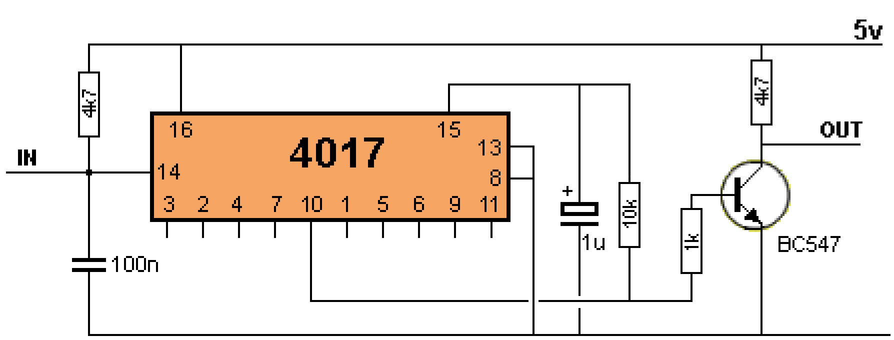
Point Motor mounted under the track.



The Point-Motor shaft moves left-right to change the points.

COIN COUNTER

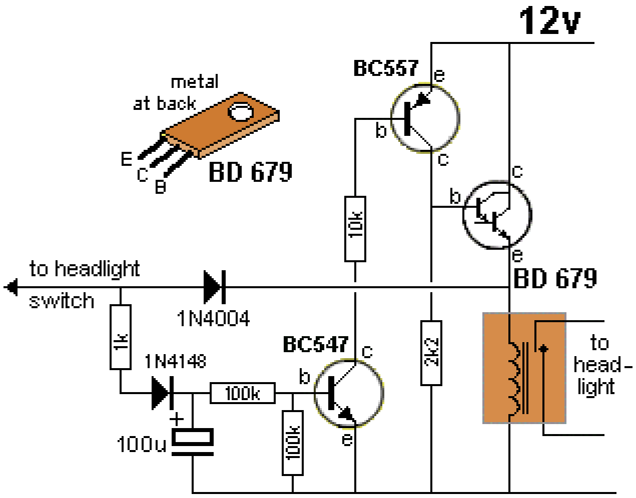
This circuit was designed for a reader who wanted to change his amusement machine from 3 coins to 4 coins.
The circuit can be modified to "divide-by" any value from 2 to 10:

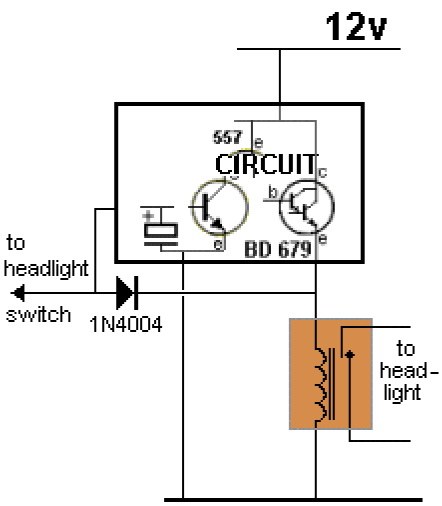


HEADLIGHT EXTENDER

This circuit extends the "ON TIME" for headlights and the circuit does not take any current when the time has expired.
When the headlights are switched OFF, the circuit keeps the lights ON

for 30 seconds.





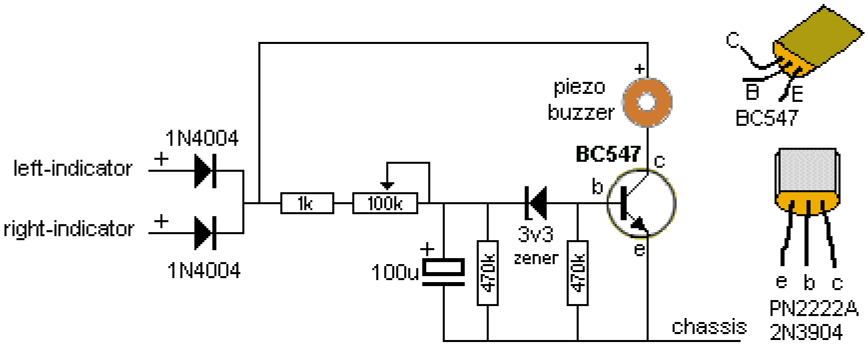
The electronics needs 3 connections. The diagram above shows these connections. The first connection is to the 12v side of the battery. The output of the circuit is the emitter of the BD679 transistor and this connects to the relay where the wire from the headlight switch is connected. Finally the circuit connects to the chassis of the car.
The "delay-time" is determined by the 100u and 100k resistor. The resistor can be increased to 470k and the capacitor can be increased to 470u. For an adjustable time-delay, use a 500k mini trim pot for the 100k resistor.

TURN INDICATOR ALARM

Many turn indicators in cars, motor bikes and golf carts are not very loud. That's why they get left ON.
Here are 2 circuits for you to experiment with and work out which is the best for your application.
They all use a piezo buzzer that has an oscillator circuit inside the case and produces a 3kHz annoying tone. We have listed two different types. TypeA produces a constant 3kHz tone that increases with loudness as the voltage increases.
TypeB is called a REVERSING BUZZER and produces a beep-beep-beep when a constant DC voltage is applied. The output increases in volume as the voltage increases.

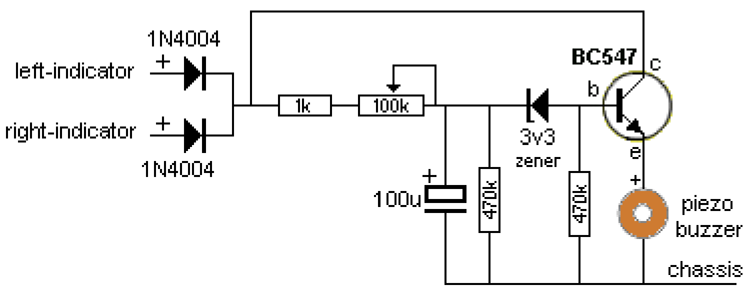
Circuit A turns on after 15 seconds to let you know the turn indicator is active.
You can use Piezo TypeA to get a beep when the turn light is ON and silence when the light is OFF.
Piezo typeB will produce a beep-beep-beep when the light is ON and

silence when it is OFF.



Beeps after 15 seconds

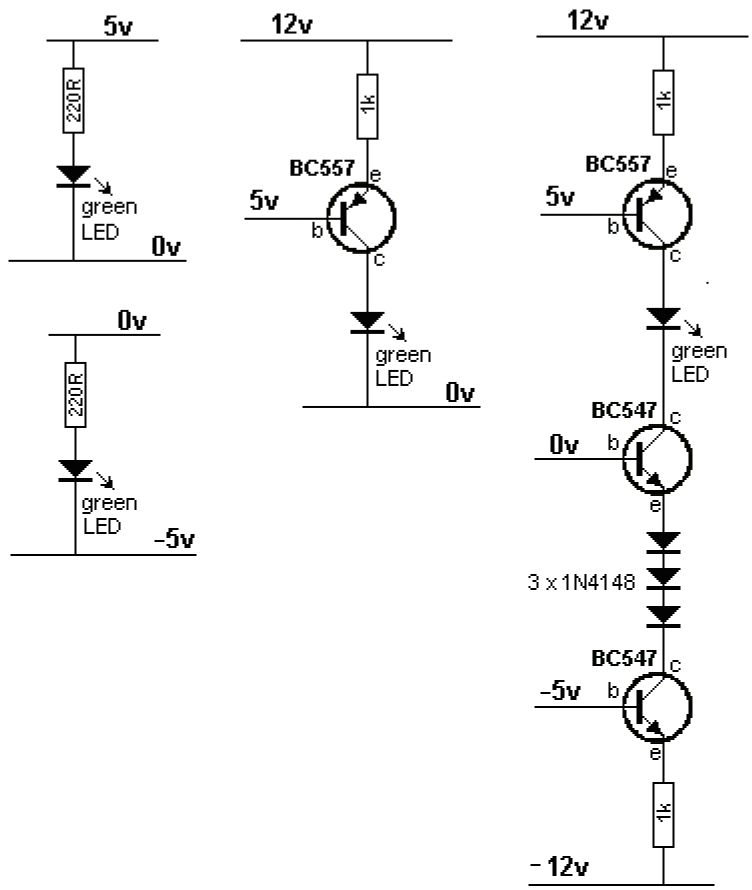
Circuit B turns on after 15 seconds and the piezo will increase in loudness.



Beeps after 15 seconds with increasing volume

A piezo buzzer requires about 15mA and operates from 3v to 12v.
Reversing buzzers are available from Talking Electronics for $4.50 each.
They are also available on the web for $20.00

SUPPLY VOLTAGE MONITOR:
These circuits will monitor supply voltages of ±5v and ±12v. They are not intended to indicate the level of the inputs. The LED will only illuminate when all the voltages are present.



SOLAR CHARGER

This is a simple circuit to keep a set of NiCads fully charged via a solar panel.
The mathematics and the circuit is the same for a 6v or 12v solar panel.
The mathematics revolves around CURRENT and not VOLTAGE.
Remember: NiCad cells are 1.2v and you will need 5 cells to produce a 6v supply.
Ni-MH cells are 1.2v and come in 1,700mAHr and 3,000mAHr (and other capacities).
You can recharge ordinary alkaline cells (1.5v) about 50 times. It has about the same capacity as NiCad after the second re-charge.

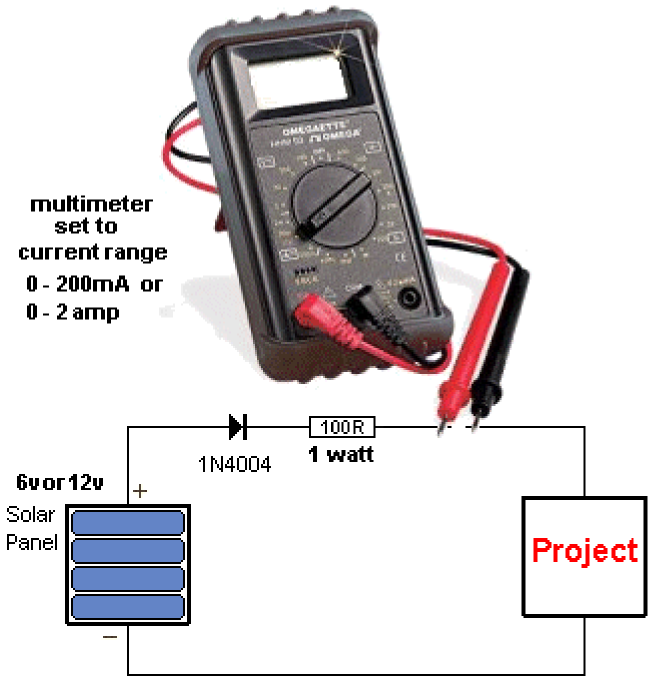
1. MEASURE THE CURRENT TAKEN BY THE PROJECT

Firstly measure the current taken by the project. If it is a constant 10mA, you will need to charge the batteries with 40mA from the solar panel, if we assume the sun shines for 8 hours per day.
If the circuit takes 1amp for 1 hour, we need to charge the batteries with 150mA for 8 hours of sunshine.
If the circuit takes 500mA for 15 minutes each hour, this is equivalent to a constant 125mA and the charging will have to be 500mA for 8 hours each day. (Even though this is equal to 3Ahr per day, the charging occupies 8 hours and thus the storage only needs to be 2Ahr and 2400mAHr cells can be used).
Our mathematics takes into account 80% efficiency in charging the cells.
If the NiCad cells are 600mAHr, the maximum charging current is 100mA.
If the cells are 2,400mAHr, the maximum charging current is 500mA.
This charging current takes into account the fact that the cells will be fully charged towards the end of each day and that's why the current should not be too high.

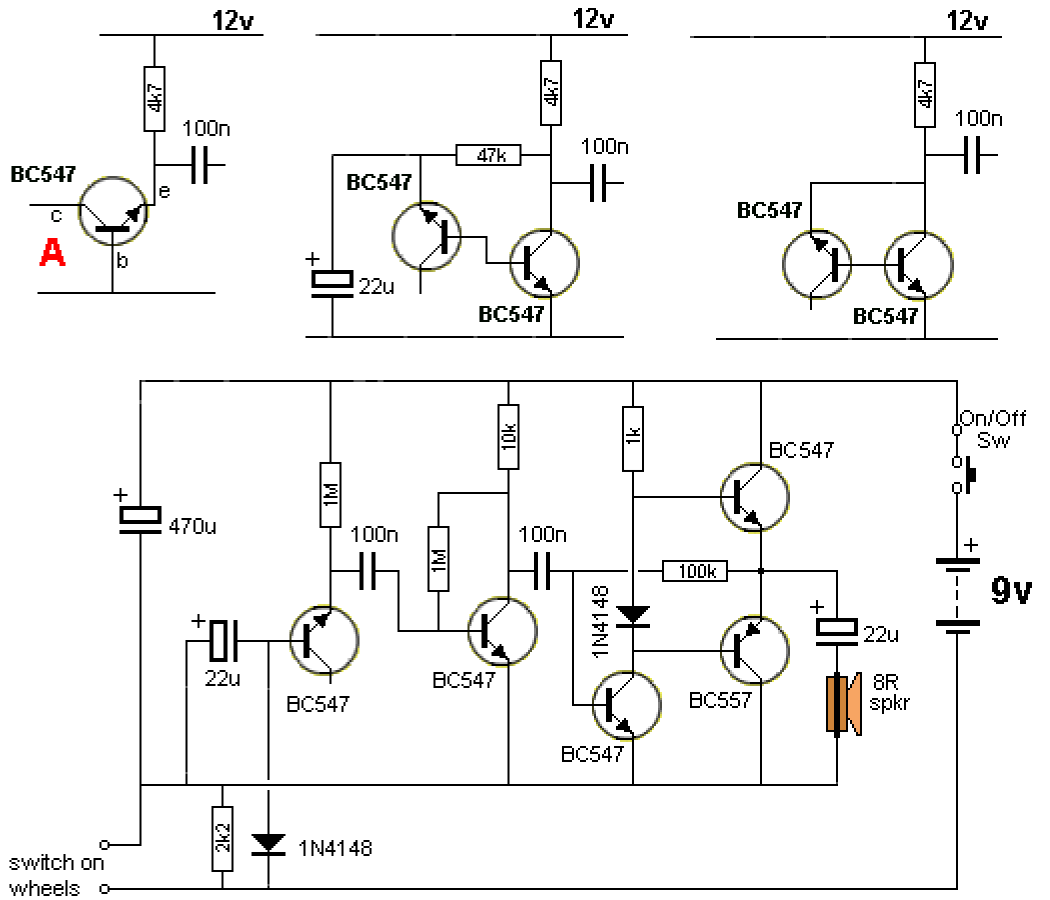
2. MEASURE THE CHARGING CURRENT

Build one of the circuits below and use a 100 ohm (1 watt) resistor for the current-limiting.

Connect a multimeter (select 0 - 500mA or 0 - 2Amp range) as shown and measure the current during the day. Take a few readings and work out and average current and approx the length of each day.
Every solar panel will deliver a different current and it is not possible to specify any values. That's why you have to take readings. If the current is too high, add another 100 ohm resistor in series. If the current is too low, place a 100 ohm resistor across the first 100 ohm resistor.



WHITE NOISE GENERATOR:
The basis of a white noise generator is the reverse connection of the base-emitter junction of a transistor as shown in fig A.
When the junction sees a voltage above about 5v, it breaks down and this causes the voltage to reduce. The junction ceases to break down and the condition repeats. The result is a waveform of a few millivolts to over 2v, depending on the value of the resistor supplying current to the junction.
This noise sounds like "ssssssssss" and can be added to an amplifier to produce all sorts of sound effects including Steam Sound for a model railway.
The waveform contains all amplitudes and frequencies from audible up to AM broadcast band.
Try the following circuits and see how they work. The supply must be over 5v and preferably more than 8v. That's why many of the circuits specify 12v and higher.

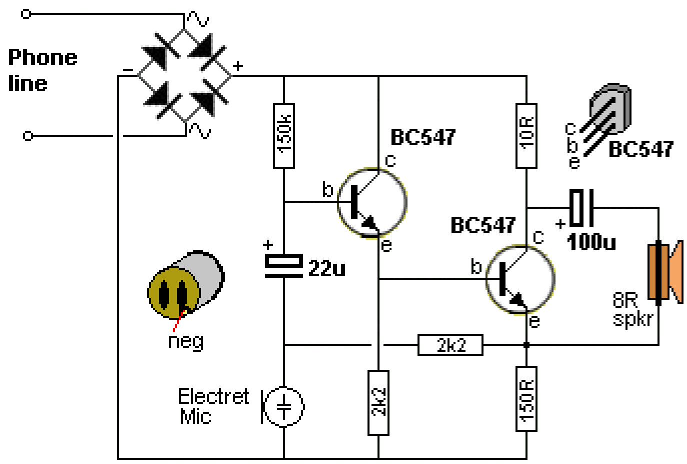


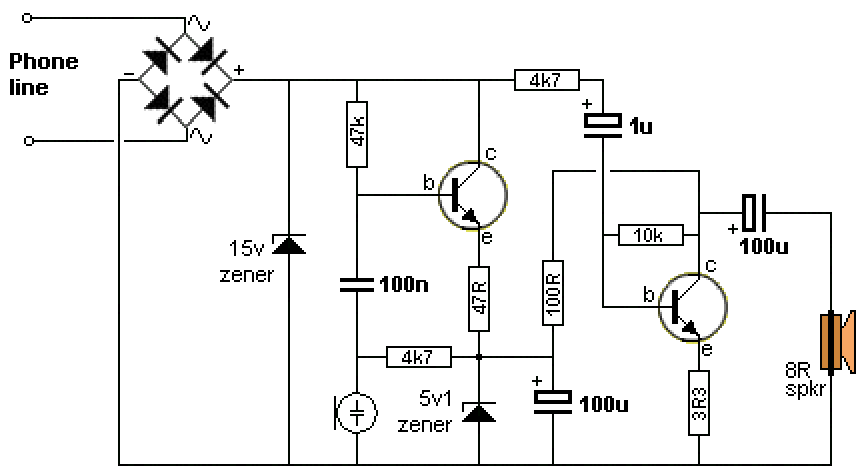
STEAM ENGINE SIMULATOR

INTERCOM or TELEPHONE HANDSET

You can make your own intercom or replace circuitry in old-style handsets with either of these circuits.
Telephone amplifier circuits are completely different to normal amplifier circuits.
For a start, they have very high negative feedback to prevent "whistle" and in telephone-speak the circuit is designed so sounds from the earpiece (receiver) are not picked up by the mouthpiece (microphone) and amplified to crate a whistle.
Secondly, the load for the amplifier is actually the relay at the exchange and the signal is picked off at the point where the amplifier connects to the relay and sent to the other telephone.
This means the supply for both the pre-amplifier and the output stage are on the same wire as the signal to the other phone.
The voltage across the first circuit is generated by the 150k turning ON the first BC547 transistor and it "pulls-up" the second transistor (a partial emitter follower).
This creates current through the 150R and a voltage is developed across this resistor so that a voltage of approx 15v is developed across the whole circuit.

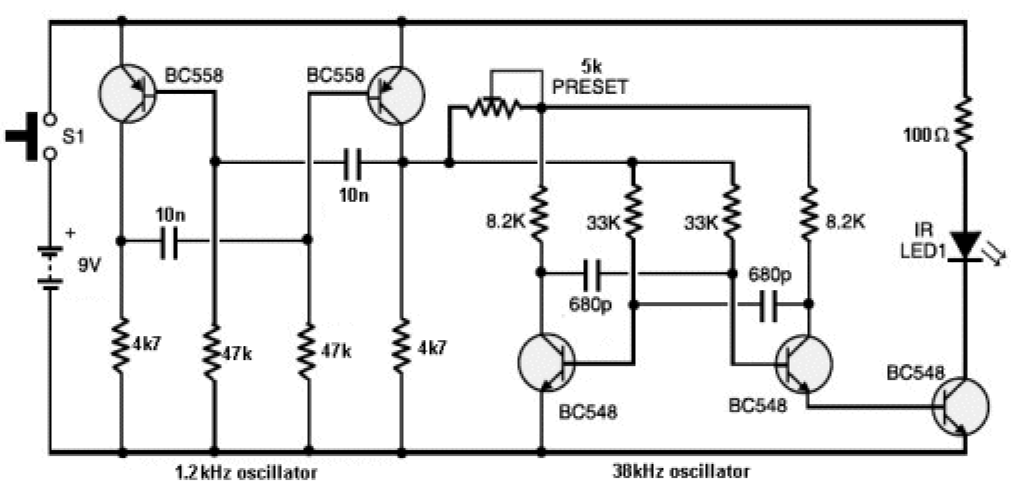
Here are two circuits for the handset:

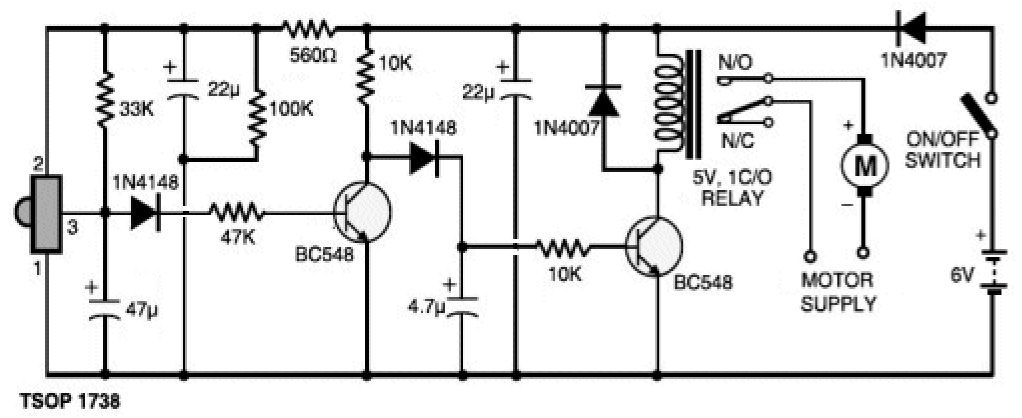




38KHz Infrared Link:

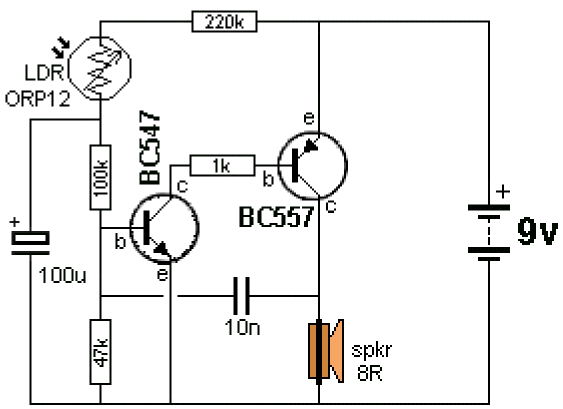
This circuit is an IR transmitter and IR receiver with a 38kHz detector TSOP 1738 in the receiver. This means the circuit will be immune to ambient light. The motor is activated when the transmitter is turned ON.





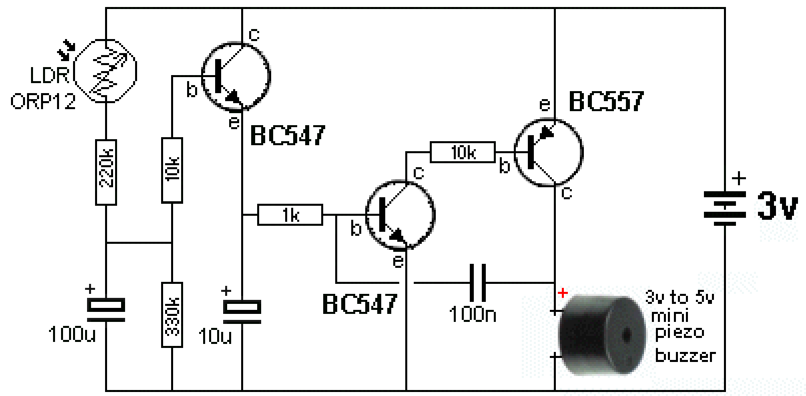
FRIDGE ALARM

This circuit will start to produce a sound about 15 seconds after the Light Dependent Resistor detects light:



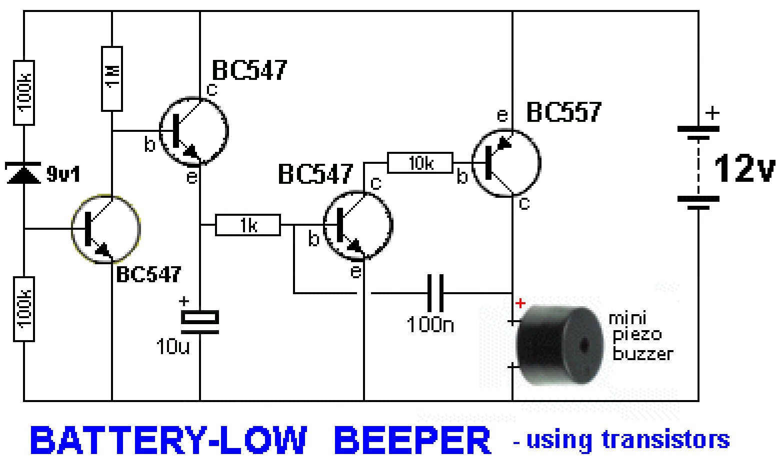
FRIDGE ALARM MkII

This circuit drives an active piezo buzzer and the circuit takes **no current** when "sitting around."
It will start to produce a sound about 15 seconds after the Light Dependent Resistor detects light.
The mini piezo buzzer contains a transistor and inductor to produce a high amplitude oscillator to drive the diaphragm and produce a loud squeal from a supply of 3v to 5v. It will not "turn on" from a slowly rising voltage so the circuit must be designed to rise rapidly when light is detected. That's the purpose of the 2nd and 3rd transistors. They form a high-gain amplifier where the output rises quickly due to the positive feedback provided by the 100n.
As soon as the second transistor starts to turn on, it turns on the 3rd transistor and the collector voltage rises. The right-plate of the 100n rises and since the 100n is uncharged, the left plate (lead) rises and increases the voltage and also the current into the base of the second transistor. This makes it turn on more and the action continues very quickly until both transistors are fully turned on. They stay turned on by the voltage (and current) provided by the first transistor.
Even though we normally see the second two transistors used as an oscillator, we can use the "rapid turn-on" feature to "kick-start" the piezo and if the middle transistor is provided with too-much voltage (current) on the base, the oscillator feature will not occur because the current into the base is too high and the 100n cannot remove this current during the turn-off period of the cycle. The only unusual feature of this circuit is the oscillator section starts to oscillate at very low amplitude when the first transistor turns off (when the LDR ceases to be illuminated) and a 10u has been added to stop this oscillation so it takes no current when at rest.
All the other designs (using a chip), take a small current when at rest and the worst circuit comes from **Future Kit**, a Thailand based kit company. You can see the discussion in **Spot The Mistake** Page 17 under FRIDGE ALARM.

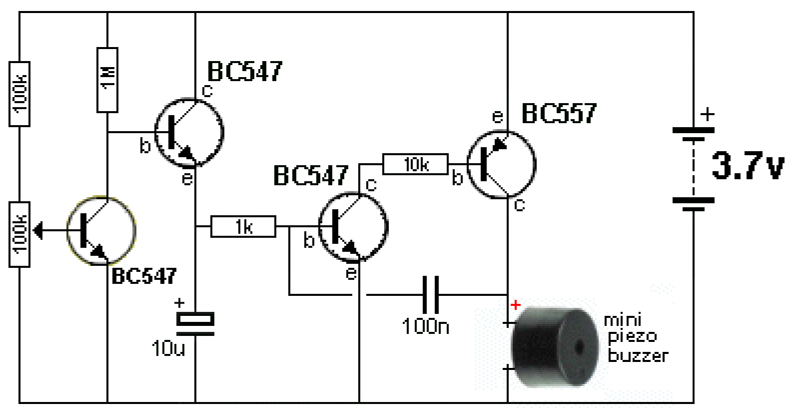


BATTERY-LOW BEEPER

If you want a simpler circuit using transistors, the following design will produce a constant beep when the battery voltage falls below 10v.
The actual voltage can be adjusted by using LEDs and diodes in place of the zener.



The mini piezo buzzer contains a transistor and inductor to produce a high amplitude oscillator to drive the diaphragm and produce a loud squeal from a supply of 5v to about 10v. It will not "turn on" from a slowly rising voltage so the circuit must be designed to rise rapidly when the voltage drop down to the "detection-point."
That's the purpose of the 3rd and 4th transistors. They form a high-gain amplifier where the output rises quickly due to the positive feedback provided by the 100n.
As soon as the third transistor starts to turn on, it turns on the 4th transistor and the collector voltage rises. The right-plate of the 100n rises and since the 100n is uncharged, the left plate (lead) rises and increases the voltage and also the current into the base of the third transistor. This makes it turn on more and the action continues very quickly until both transistors are fully turned on. They stay turned on by the voltage (and current) provided by the first transistor.
Even though we normally see these two transistors used as an oscillator, we can use the "rapid turn-on" feature to "kick-start" the piezo and if the third transistor is provided with too-much voltage (current) on the base, the oscillator feature will not occur because the current into the base is too high and the 100n cannot remove this current during the turn-off period of the cycle. The only unusual feature of this circuit is the oscillator section starts to oscillate at very low amplitude when the second transistor turns off (when the battery voltage rises) and a 10u has been added to stop this oscillation so it takes no current when the buzzer is not producing a tone. The only stages that take any quiescent current are the zener and the 1M collector load resistor.

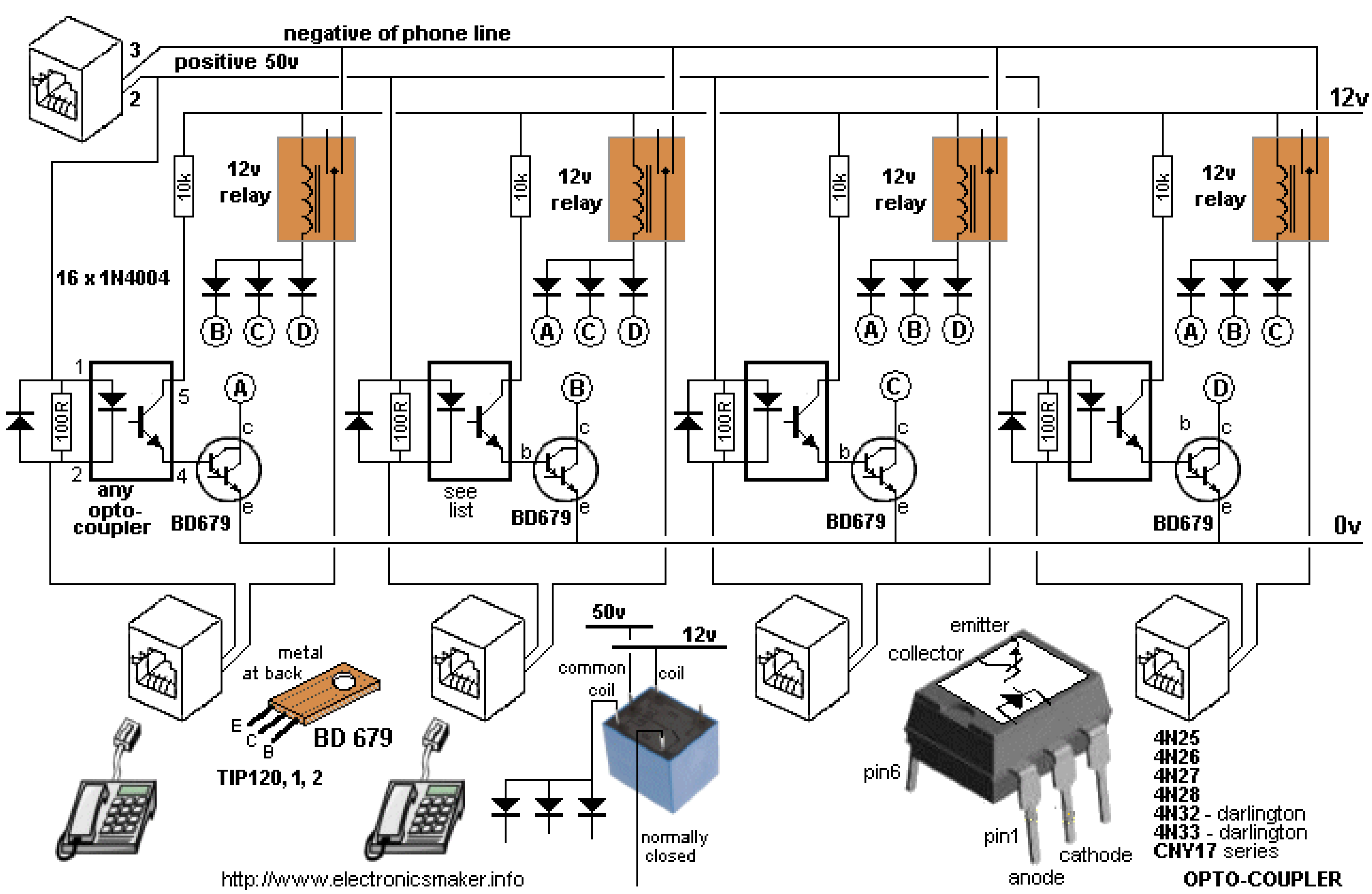


3.7v LI-ION CELL LOW VOLTAGE BEEPER

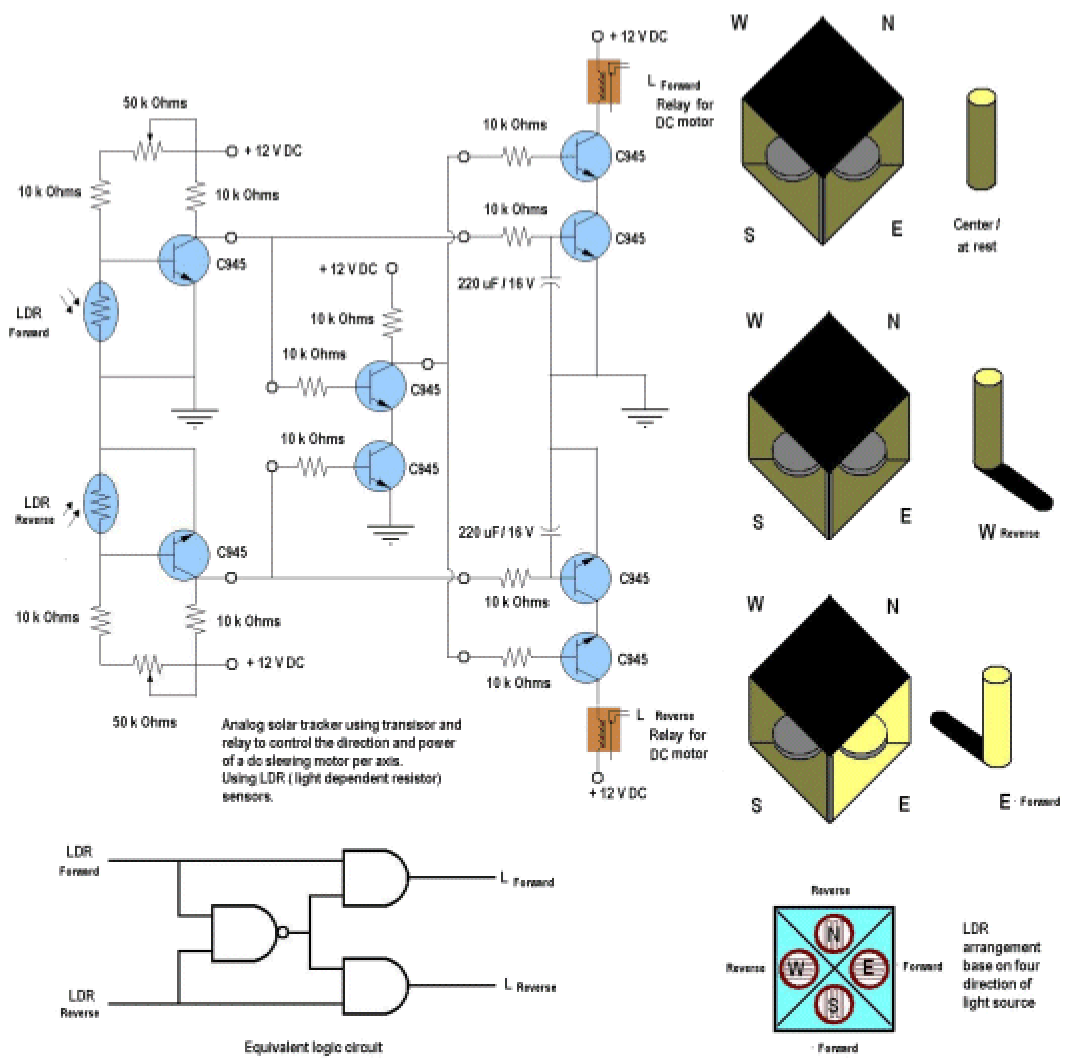
This circuit will buzz when the voltage drops to a pre-set level.
To adjust the circuit, get as many 10,000u electrolytics as possible and use them in place of the Li-ion cell.
Charge the electrolytics with the Li-Ion cell and remove it.
The circuit takes a very amount of current and the voltage across the electrolytics will gradually drop. Monitor this with a digital meter and set the 100k pot to the required voltage.

4 PHONE SECURITY:

See full article on: http://www.electronicsmaker.info



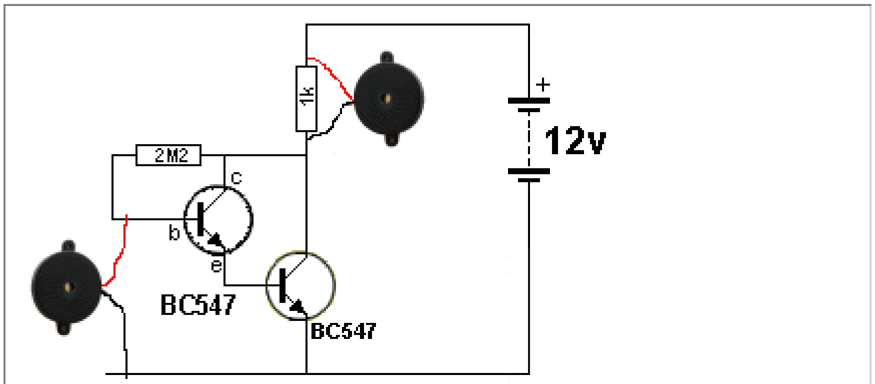
SOLAR TRACKER:



Click circuit for large image

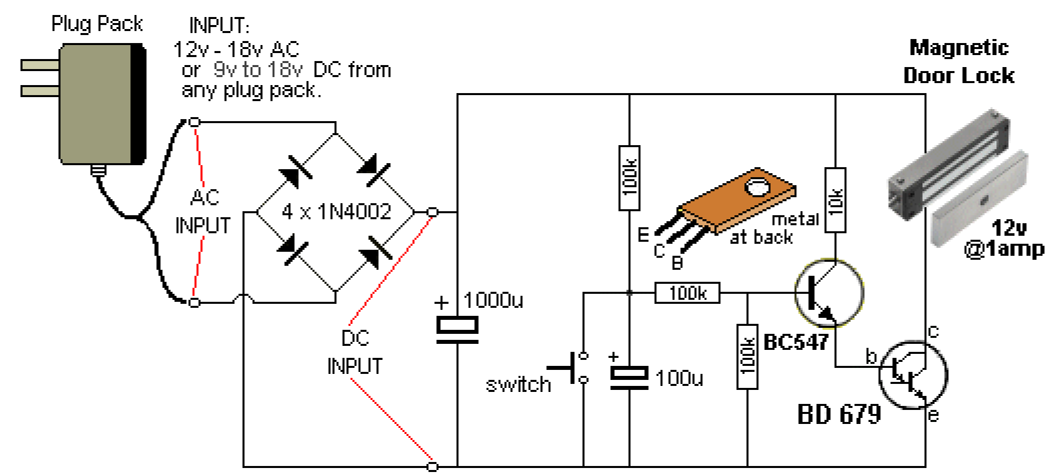
SIMPLE SONIC DETECTOR:

This is a simple feedback circuit that produces a whistle called a FEEDBACK WHISTLE.
This terrible sound was very common in old amplifiers when the microphone was placed too near the speaker.
All you need is a high-gain amplifier and a microphone. We have used a piezo diaphragm for both the microphone and speaker.
The circuit works best on 12v but will produce good results on 6v or 9v.
Vary the distance between the two piezos and turn one over and lift it off the bench to see the different effects and range. Move your hand closer to the piezos and see how the frequency changes. This is due to the length of the wave and if you are located at a distance where the wave does not add to the vibration of the receiving diaphragm, you get silence.



The Circuit produces a FEEDBACK WHISTLE

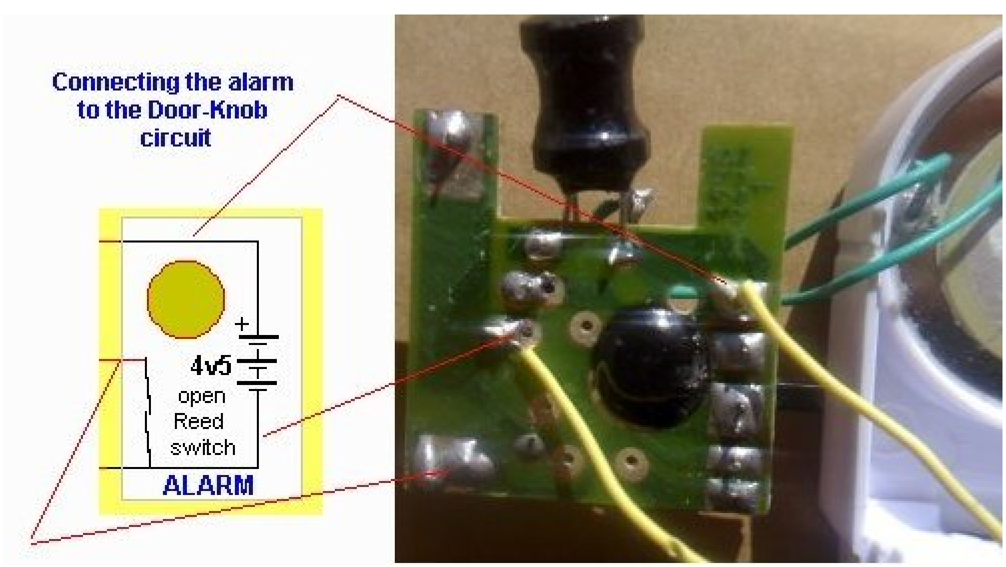
MAGNETIC DOOR LOCK DELAY:

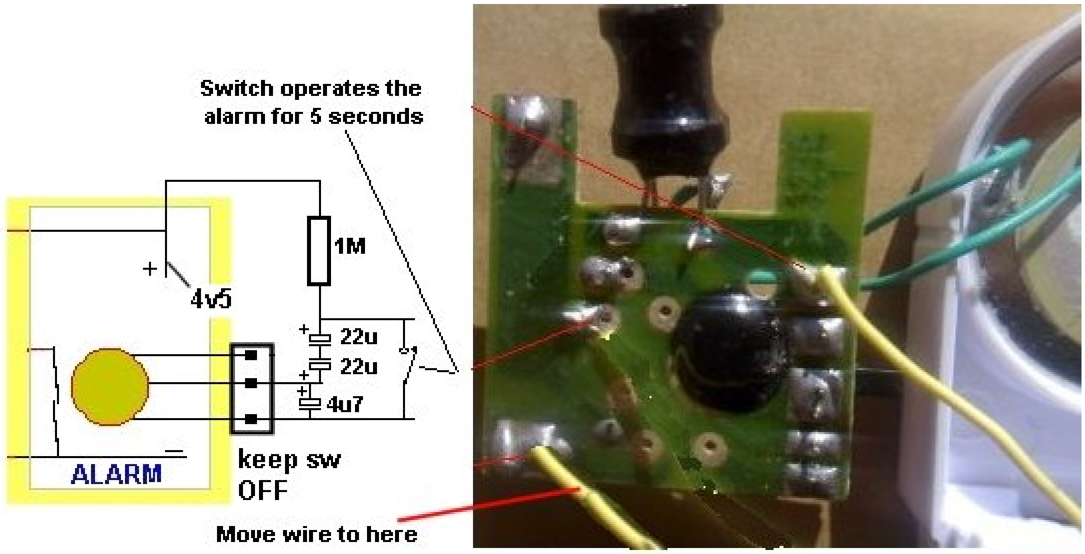


This circuit turns **OFF** the Magnetic Door Lock for 10 second to 30 seconds to allow you to enter. It turns **ON** after 10 seconds to 30 seconds.

5 SECOND ALARM:

This circuit operates the alarm for 5 seconds, even if the switch is kept closed:





The original reed switch can be used but the bottom connection to the board must be isolated and re-wired.
The reed switch cannot be de-soldered as it will fall apart. Change the value of the 4u7 electrolytic to increase the time. Closing the switch (in the circuit diagram above) operates the alarm.
When the voltage between the middle terminal of the slide switch and the lower terminal is reduced to 0v, the circuit operates. A very small current comes from the COB module via the middle pin of the slide switch and this current charges the 4u7 to 4.5v and the circuit turns OFF.
At the same time the two 22u are fully discharged.
When the switch is closed, the 4u7 is discharged via the two 22u electrolytics and the alarm is activated. If the switch is immediately released, the 4u7 takes time to charge via the COB module.
If the switch is kept closed, the COB module charges the 4u7 and the 22u electrolytics and eventually turns OFF. If the switch is now opened, the 22u electrolytics discharge via the 1M. This takes a considerable time and the alarm cannot be re-activated for a few seconds.

MORE CIRCUITS TO BE ADDED HERE:

Circuit Symbols

The list below covers almost every symbol you will find on an electronic circuit diagram. It allows you to identify a symbol and also draw circuits. It is a handy reference and has some symbols that have never had a symbol before, such as a Flashing LED and electroluminescence panel.
Once you have identified a symbol on a diagram you will need to refer to specification sheets to identify each lead on the actual component.
The symbol does not identify the actual pins on the device. It only shows the component in the circuit and how it is wired to the other components, such as input line, output, drive lines etc. You cannot relate the shape or size of the symbol with the component you have in your hand or on the circuit-board.
Sometimes a component is drawn with each pin in the same place as on the chip etc. But this is rarely the case.
Most often there is no relationship between the position of the lines on the circuit and the pins on the component.

That's what makes reading a circuit so difficult.

This is very important to remember with transistors, voltage regulators, chips and so many othe r components as the position of the pins on the symbol are not in the same places as the pins or leads on the component and sometimes the pins have different functions according to the manufacturer. Sometimes the pin numbering is different according to the component, such as positive and negative regulators.

These are all things you have to be aware of.

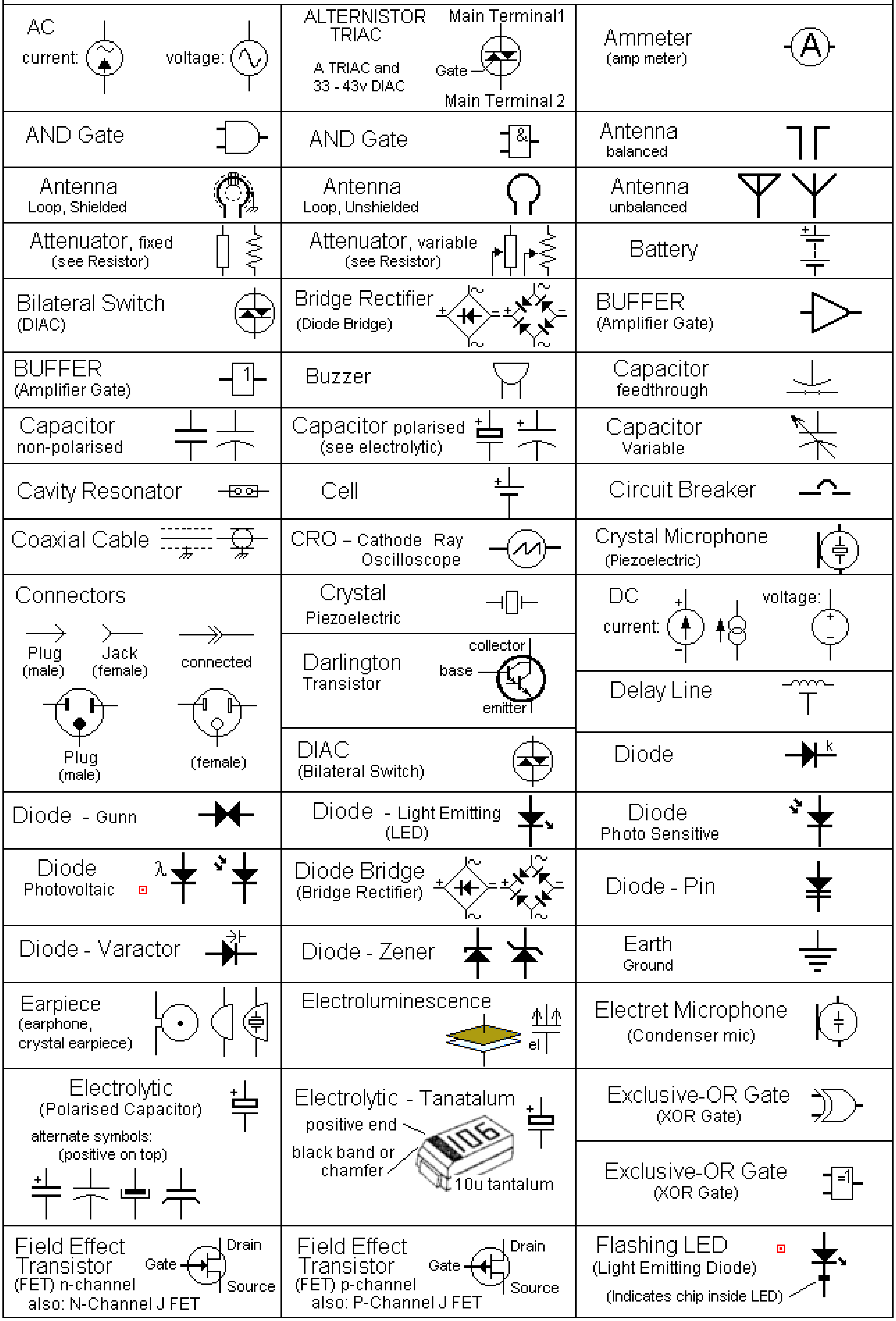
You must to refer to the manufacturer's specification sheet to identify each pin, to be sure you have identified them correctly.

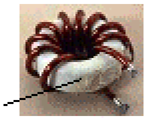
Colin Mitchell

CIRCUIT SYMBOLS

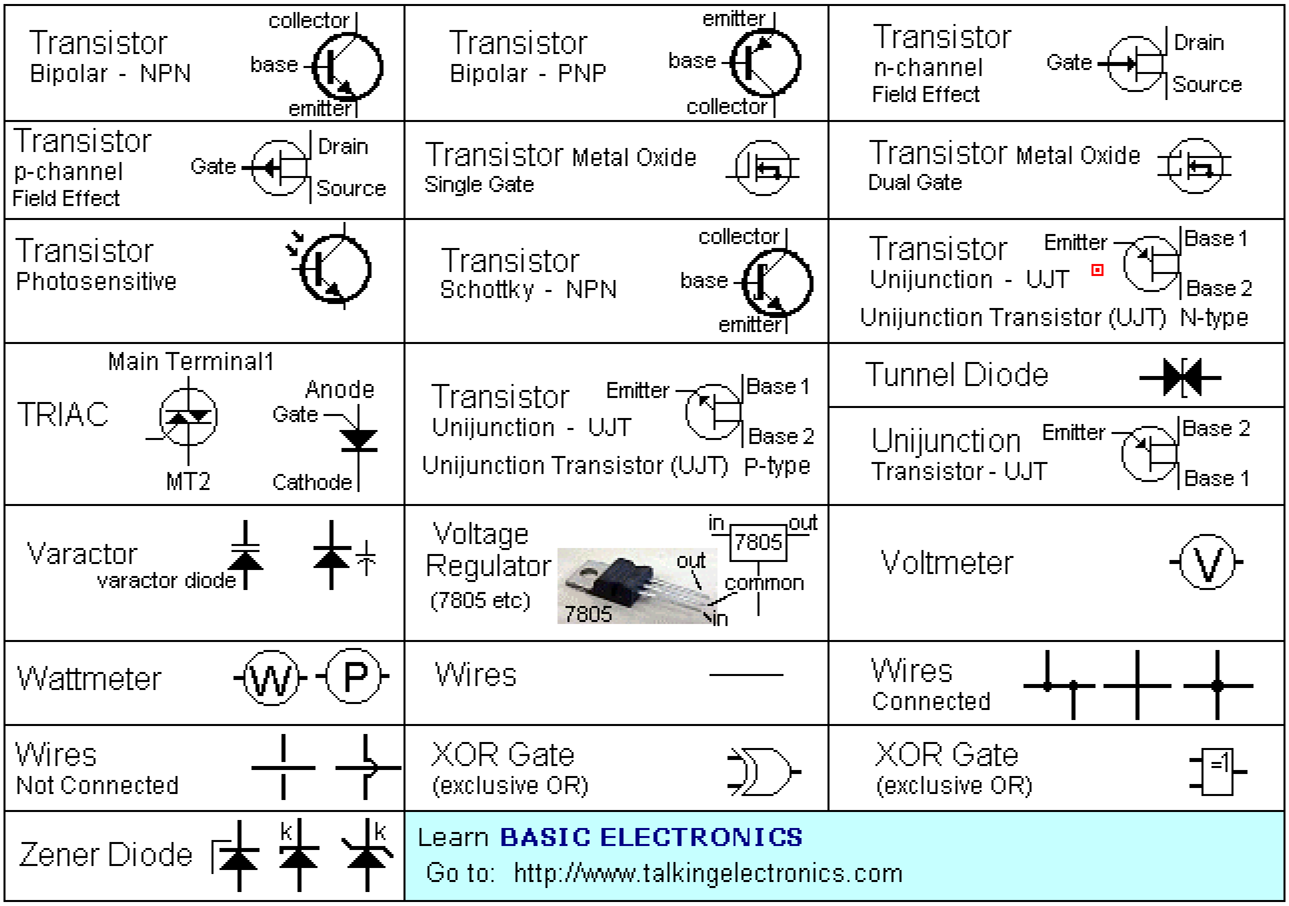
Some additional symbols have been added to the following list. See **Circuit Symbols** on the index of Talking Electronics.com

CIRCUIT SYMBOLS by TALKING ELECTRONICS



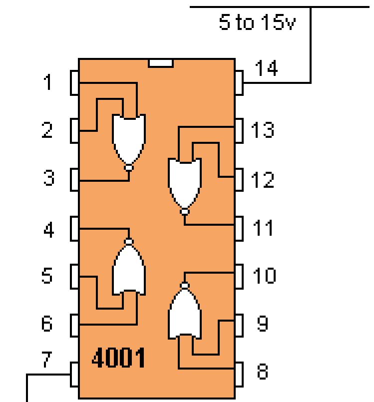
Ferrite Bead	Fuse	Galvanometer G
Globe	Ground Chassis	Ground Earth
Heater (immersion heater) (cooker etc)	IC Integrated Circuit power ground	Inductor Air Core
Headphone		Inductor Iron Core or ferrite core 
Inductor Tapped	Inductor Variable	Integrated Circuit 
Inverter (NOT Gate)	INVERTER (NOT Gate) 1	
Jack Co-axial	Jack Phone (Phone Jack)	Jack Phone (Switched)
Jack Phone (3 conductor)	Key Telegraph (Morse Key)	Lamp Incandescent
Lamp - Neon	LASCR (Light Activated Silicon Controlled Rectifier)	LDR (Light Dependent Resistor)
LASER diode laser diode photo diode	Light Emitting Diode (LED) 	Light Emitting Diode (LED - flashing) (Indicates chip inside LED)
Mercury Switch	Micro-amp meter (micro-ammeter) µA	Microphone (see Electret Mic) 
Microphone (Crystal - piezoelectric)	Milliamp meter (milli-ammeter) mA	Motor MOT
NAND Gate	NAND Gate &	Nitinol wire "Muscle wire"
Negative Voltage Connection	NOR Gate	NOR Gate ≥1
NOT Gate Inverter	NOT Gate Inverter 1	Ohm meter Ω
Operational Amplifier (Op Amp)	Optocoupler (Transistor output)	Opto Coupler (Opto-isolator) a k c e Photo-transistor output
Optocoupler (Darlington output)	Opto Coupler (Opto-isolator) a k c e TRIAC output	OR Gate
OR Gate ≥1	Oscilloscope see CRO	Outlet (Power Outlet)
Piezo Diaphragm	Photo Cell (photo sensitive resistor)	Photo Diode
Photo Darlington Transistor	Photo FET (Field Effect Transistor) Gate Drain Source	Photo Transistor

Photovoltaic Cell (Solar Cell) + λ +	Piezo Tweeter (Piezo Speaker)	Positive Voltage Connection +
Potentiometer (variable resistor)	Programmable Unijunction Transistor PUT gate anode cathode	Rectifier Silicon Controlled (SCR) Anode Gate Cathode
Rectifier Semiconductor k	Reed Switch N	Relay - spst
Relay - spdt	Relay - dpst	Relay - dpdt
Resistor Fixed	Resistor Non Inductive	Resistor preset
Resistor variable	Resonator 3-pin	RFC Radio Frequency Choke
Rheostat (Variable Resistor)	Saturable Reactor	Schmitt Trigger (Inverter Gate)
Schottky Diode (also Shottky) Low forward voltage 0.3v Fast switching also called Schottky Barrier Diode k k	Shielding Signal Generator	Shockley Diode k 4-layer PNPN device Remains off until forward current reaches the forward break-over voltage.
Silicon Bilateral Switch (SBS) T_2 Terminal Gate T_1 Terminal e.g: BS08D T_2 G T_1	Silicon Unilateral Switch (SUS) Anode Gate Cathode(k) A G k	Silicon Controlled Rectifier (SCR) Anode Gate Cathode Solar Cell + λ +
Surface Mount c b SOT-23 e b c e b c e k k k A no connection & LED	Switch - spst Switch - spdt Switch - dpst Switch - dpdt Switch - mercury tilt switch Spark Gap	Switch - process activated normally open: normally closed: Flow Level Pressure Temperature Speaker 8R
Switch - push (Push Button)	Switch - push off (used in alarms etc)	Switch - Rotary
Test Point Thermal Probe NTC t° = ? **NTC:** as temp rises, resistance decreases	Thyristors: Main Terminal1 Bilateral Switch Anode Gate Cathode MT2 Anode Gate Cathode **DIAC** **SCR** **TRIAC** **TRIAC**	Thermocouple Tilt switch mercury Touch Sensor
Transformer Air Core	Transformer Iron Core	Transformer (Tapped Primary/Sec)

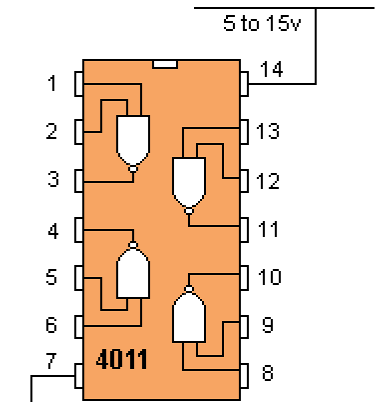


IC PINOUTS

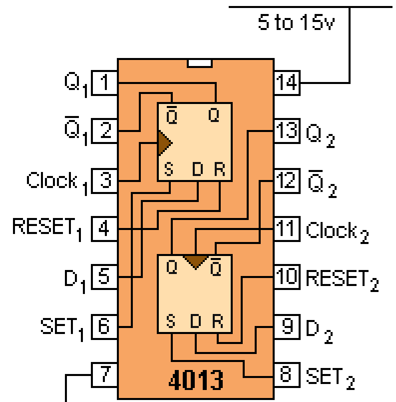
The following list covers just a few of the IC's on the market and these are the "simple" or "basic" or "digital" or "op-amp" IC's suitable for experimenting.
When designing a circuit around an IC, you have to remember two things:
1. Is the IC still available? and
2. Can the circuit be designed around a microcontroller?
Sometimes a circuit using say 3 or 4 IC's can be re-designed around an 8-pin or 16-pin microcontroller and the program can be be kept from prying eyes due to a feature called "code protection." A microcontroller project is more up-to-date, can be cheaper and can be re-programmed to alter the features.
This will be covered in the next eBook. It is worth remembering - as it is the way of the future.



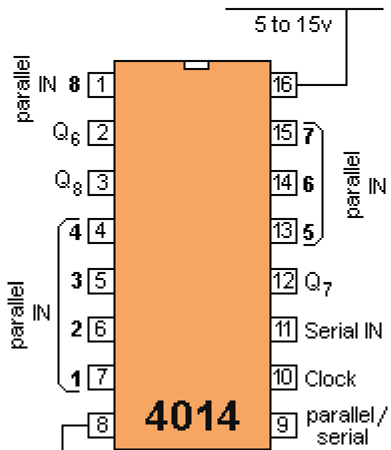
QUAD 2-INPUT NOR gate



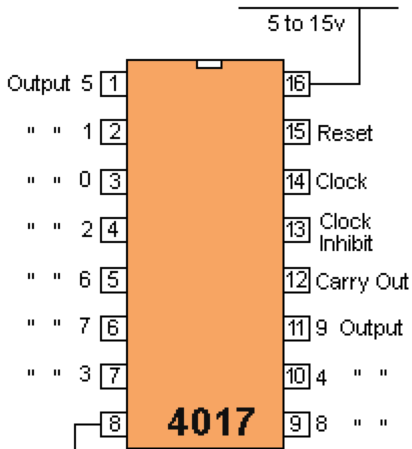
QUAD 2-INPUT NAND gate



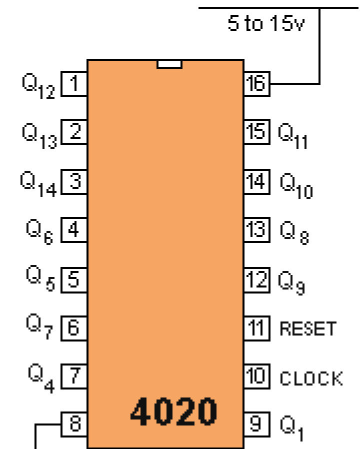
DUAL D FLIP FLOP



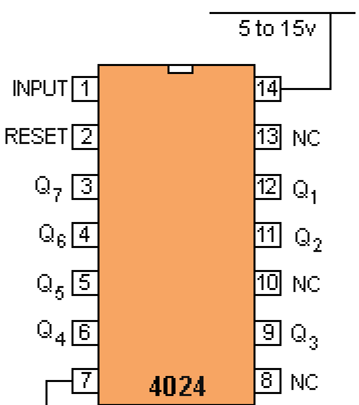
8-BIT SHIFT REGISTER



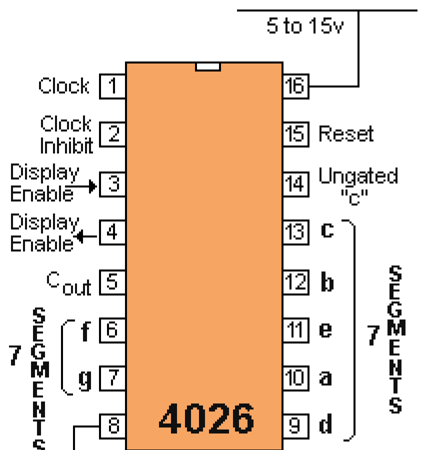
DECADE COUNTER DIVIDER



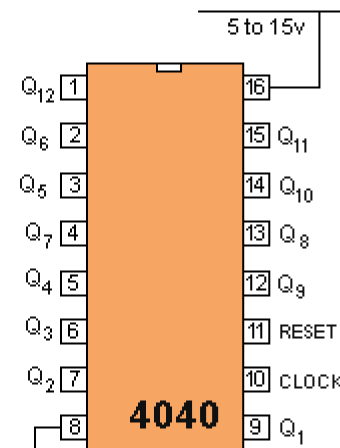
14 STAGE BINARY COUNTER



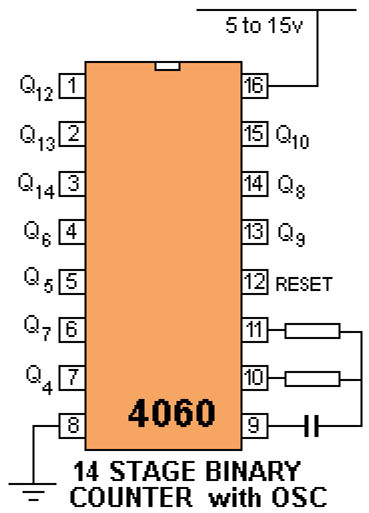
7-STAGE BINARY COUNTER

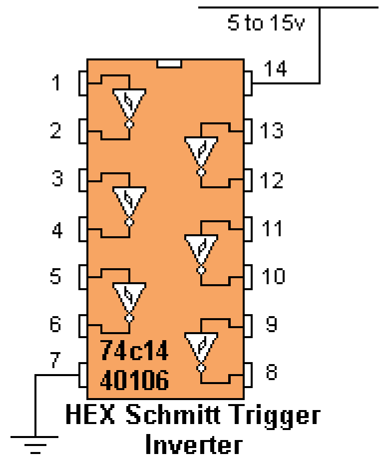


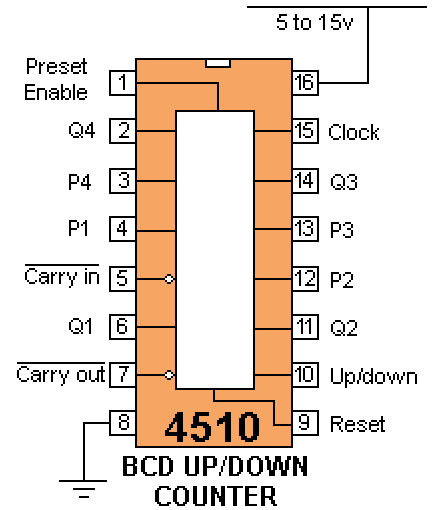
7-Segment Display Driver

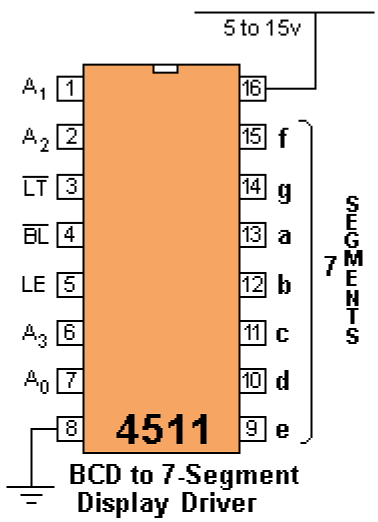


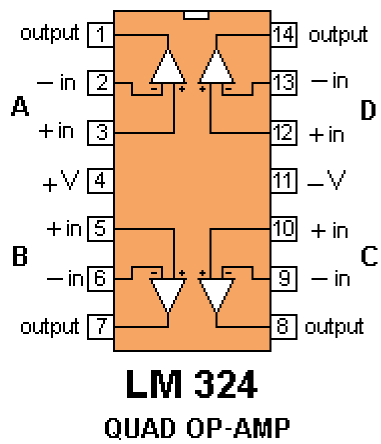
12 STAGE BINARY COUNTER

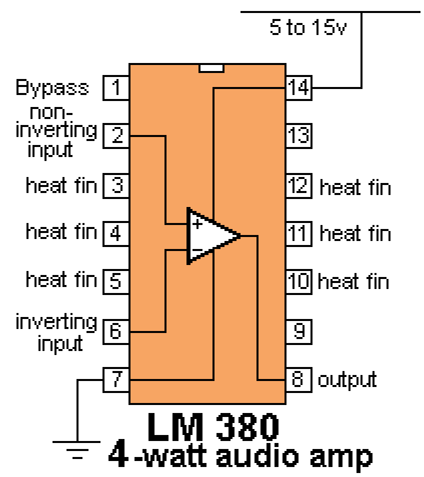


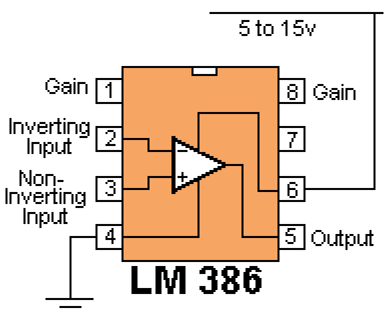


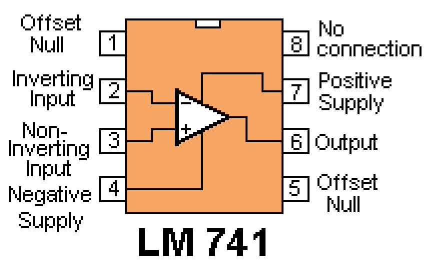


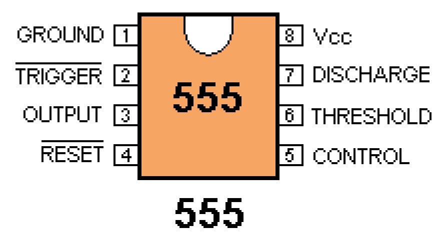


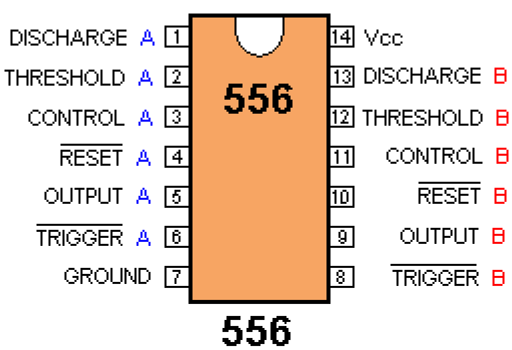


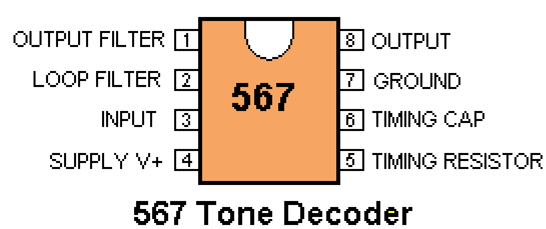








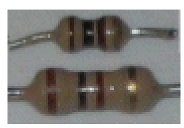




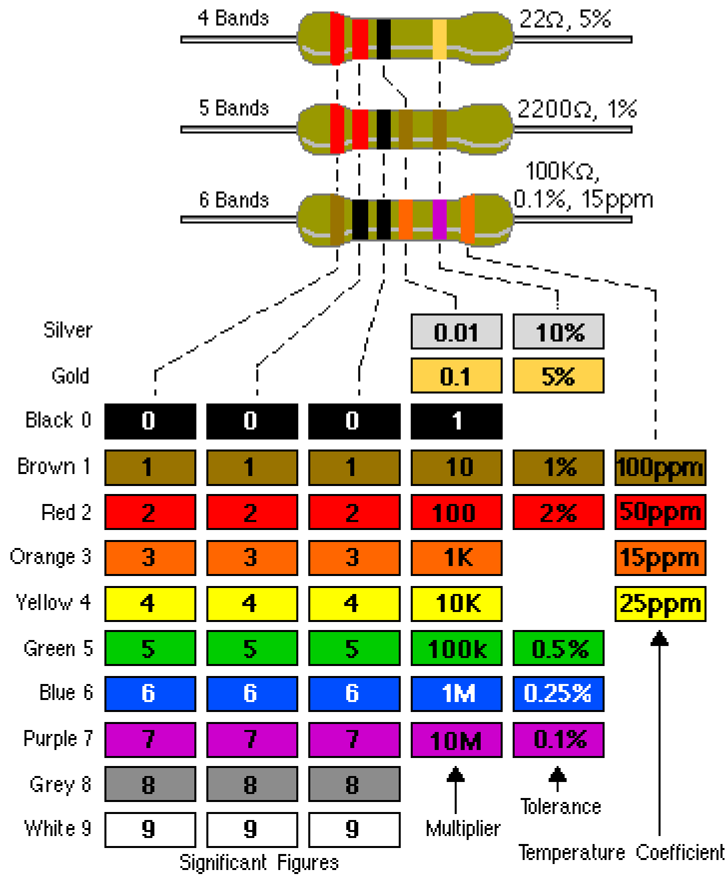
All the resistor colours:

This is called the "normal" or "3 colour-band" (5%) range. If you want the 4 colour-band (1%) series, refer to Talking Electronics website and click: **Resistors 1%** on the left index. Or you can use the table below.

1R0	10R	100R	1k0
1R2	12R	120R	1k2
1R5	15R	150R	1k5
1R8	18R	180R	1k8
2R2	22R	220R	2k2
2R7	27R	270R	2k7
3R3	33R	330R	3k3
3R9	39R	390R	3k9
4R7	47R	470R	4k7
5R6	56R	560R	5k6
6R8	68R	680R	6k8
8R2	82R	820R	8k2
10k	100k	1M0	10M
12k	120k	1M2	22M
15k	150k	1M5	
18k	180k	1M8	0R1
22k	220k	2M2	R22
27k	270k	2M7	0R0 zero ohm (link)
33k	330k	3M3	
39k	390k	3M9	
47k	470k	4M7	
56k	560k	5M6	
68k	680k	6M8	
82k	820k	8M2	



$^{1}/_{10}{}^{th}$ watt
and
0.25 watt



Resistor Color Code System

MAKE ANY RESISTOR VALUE:
If you don't have the exact resistor value for a project, don't worry. Most circuits will work with a value slightly higher or lower.
But if you want a particular value and it is not available, here is a chart.
Use 2 resistors in series or parallel as shown:

Required Value	R1	Series/ Parallel	R2	Actual value:
10	4R7	S	4R7	9R4
12	10	S	2R2	12R2
15	22	P	47	14R9
18	22	P	100	18R
22	10	S	12	22
27	22	S	4R7	26R7
33	22	S	10	32R
39	220	P	47	38R7
47	22	S	27	49
56	47	S	10	57
68	33	S	33	66
82	27	S	56	83

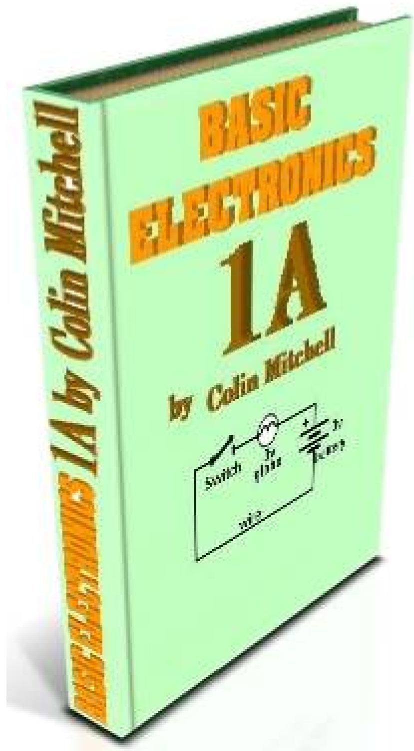
There are other ways to combine 2 resistors in parallel or series to get a particular value. The examples above are just one way.
4R7 = 4.7 ohms

MAKE ANY CAPACITOR VALUE:

If you don't have the exact capacitor value for a project, don't worry. Most circuits will work with a value slightly higher or lower.
But if you want a particular value and it is not available, here is a chart.
Use 2 capacitors in series or parallel as shown. "p" is "puff" but can be "n" (nano) or "u" (microfarad).

Required Value	C1	Series/ Parallel	C2	Actual value:
10	4p7	P	4p7	9p4
12	10	P	2p2	12p2
15	22	S	47	14p9
18	22	S	100	18p
22	10	P	12	22
27	22	P	4p7	26p7
33	22	P	10	32p
39	220	S	47	38p7
47	22	P	27	49
56	47	P	10	57
68	33	P	33	66
82	27	P	56	83

There are other ways to combine 2 capacitors in parallel or series to get a particular value. The examples above are just one way. 4p7 = 4.7p



For any enquiries email Colin Mitchell

The Power Supply

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THE POWER SUPPLY

There are many different types of power supplies, including batteries, plug packs, switch-mode supplies and a basic transformer and bridge.
Most modern equipment is powered by a very compact power supply called a **SWITCH MODE POWER SUPPLY**. (**SMPS**)
It uses advanced technology and a chip to drive the circuitry at a very high frequency so the isolating transformer can be very small.
We will not be covering this technology.
However the simplest power supply consist of a transformer, one or more diodes and a large filter capacitor (electrolytic).
This is a basic **POWER SUPPLY** and we will cover it.
It will involve connecting to the **MAINS** and this is very dangerous.
But first we will cover the **BATTERY** as a **POWER SUPPLY**.

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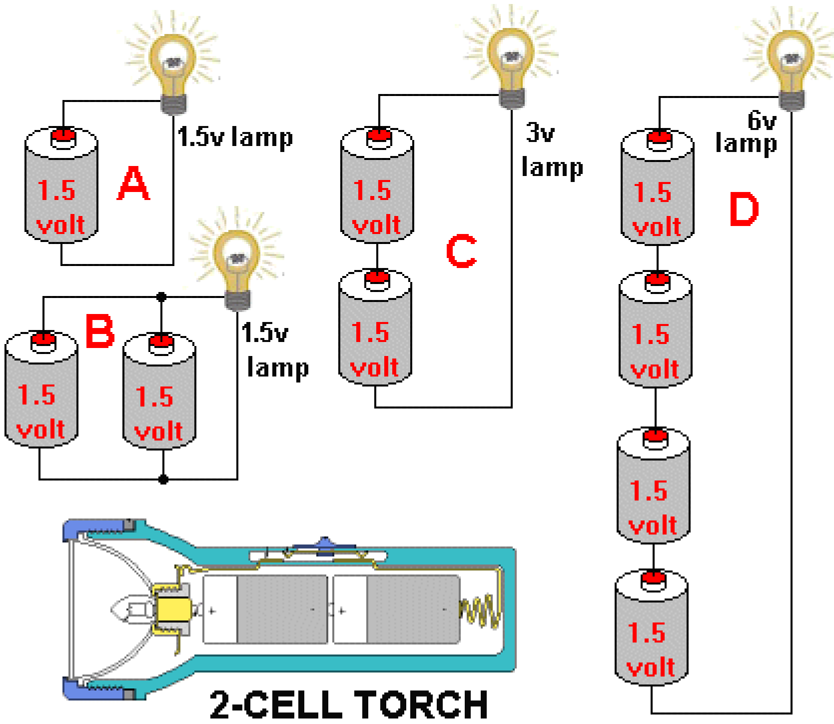
CELLS in PARALLEL AND SERIES



The diagrams show cells in **PARALLEL** and **SERIES**.
Diagram **A** shows a single 1.5v cell connected to a 1.5v globe.
Diagram **B** shows two 1.5v cells connected in PARALLEL to a 1.5v globe. 2 cells in parallel are just like one big cell.
Diagram **C** shows two 1.5v cells connected in SERIES to a 3v globe. When cells are connected in SERIES, you add the voltages of each cell.
Diagram **D** shows four 1.5v cells connected in SERIES to a 6v globe. The voltage of the globe must be the same as the voltage produced by the cells otherwise the globe will be too dull or it will "burn-out."
When two or more cells are connected in **SERIES** the result is called a **BATTERY**.

Fig 1. CELLS in PARALLEL AND SERIES

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CELLS in a 9v BATTERY

There are 6 cells in a 9v battery. But the cells are very small and they don't hold much ENERGY.

This means 2 things:
The battery cannot deliver a high current and it can only deliver a small (low) current for a short period of time.
The first two pictures are commonly called "dry cells" and the other two pictures are Alkaline cells.
Alkaline cells are more expensive but they can deliver 3 times more energy than a dry-cell.

Fig 2. The CELLS in a 9v BATTERY

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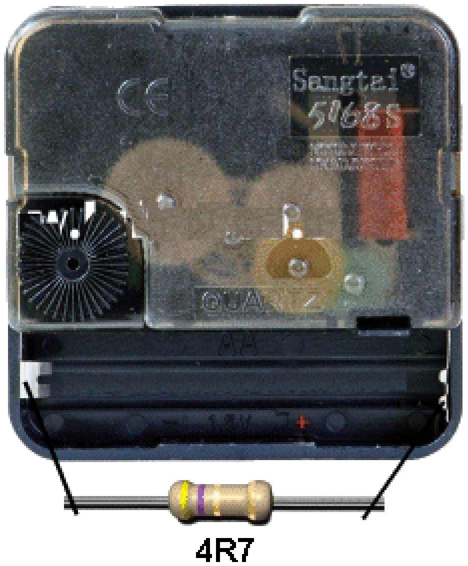
HOW LONG WILL A BATTERY LAST?

When you buy a battery, it has already lost some of its energy via leakage inside the cells so it is impossible to work out how long it will last.
Secondly, the life of a battery depends on the current drawn from it.
It also depends on how long it is used for during each "session" and how much rest it gets.
It also depends on the temperature of the day and the "end-voltage" - this is the voltage of the "dead battery" and it is different for each piece of equipment.
It also depends on the quality of the chemicals used in the construction and the sealing of each cell to prevent internal leakage. There are so many variables.
The average **9v Carbon-Zn** will deliver **300mAHr**
The average **9v Alkaline** will deliver **500mAHr**

What is mAhr?
mA is milliamp. There are 1,000mA in 1 amp. mAHr is milliamp multiplied by hours.
A 9v Carbon-Zn battery will deliver 1mA for 300 hours.
A 9v Carbon-Zn battery will deliver 10mA for 30 hours.
A 9v Carbon-Zn battery will deliver 15mA for 20 hours. (If you take more than 15mA, the capacity of the battery will be less than 300mAHr).

But there is one major difference between the two types of 9v battery.
A new **9v Carbon-Zn** battery will deliver about 200mA for a very short period of time.
A new 9v Alkaline battery will deliver about 2 Amp (2,000mA) for a very short period of time.
That's why you can use a 9v alkaline battery in a Stun Gun. It takes over 1 amp to produce the 50,000 volt spark.
A "**AAA**" dry-cell has approx 600mAHr @ 30mA current
A **"AA"** dry-cell has approx 1,000mAHr @ 75mA current
A **"C"** dry-cell has approx 2.5AHr @ 150mA current
A **"D"** dry-cell has approx 5.5AHr @ 250mA current
Alkaline cells have approx 2 times more capacity and will perform about 5 times better at high current demand.
You can test rechargeable cells to determine if they still have full capacity by connecting them to the clock mechanism on the left. The 4R7 resistor will draw a considerable current and the clock will stop when the battery reaches 0.7v. Start the time a 12:00 and the hands will show the number of hours of operation.
This is a "comparison test" and by testing other cells you will be able to determine if any of the cells are faulty.



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THE BATTERY as a POWER SUPPLY

A battery is an ideal POWER SUPPLY because it is CHEAP, it will deliver a fixed VOLTAGE and plenty of CURRENT when required.

There are many different types of batteries. Some are RECHARGEABLE, some are HIGH CURRENT and some are LOW COST.

To cover all the cells and sizes would take a book so we will limit our discussion to a few different types.
The simplest battery is made from AA or AAA cells.
Use the largest cells you can fit into your project. This will allow the project to operate for a long period of time. It will be the cheapest and most economical way to power a project and give the best performance.

BATTERY TERMS (Terminology)

A **BATTERY** is a good **POWER SUPPLY** because it will deliver a small or large **CURRENT** as required by the project.
A battery supplies **DC VOLTAGE** - the letters **DC** actually mean **Direct Current** and that's one of the unusual concepts of electronics.
As a battery is "used" the energy is removed by eating the zinc case and eventually we say the battery is **FLAT**. This means it is not suitable for the application because either the voltage is too low or it will not deliver the required current.
A 'Flat" battery can be detected by the volume (loudness) of an amplifier decreasing, the sound becoming distorted, or the globe in a torch becoming dull.
A battery gets "used up" and its **INTERNAL RESISTANCE INCREASES**.
This causes the output voltage to decrease and the current will also decrease.
To fix the problem, simply replace the dry cells or recharge the rechargeable cells.

The **CAPACITY** of a battery:
Capacity is the total amount of energy stored in a cell.
It is a combination of the voltage of the cell and the length of time a current can be delivered.
It is measured in **mW-hrs** or **W-hrs.** In other words it is volts x amps x hours.
Cells with a voltage of 3.6v have an advantage over cells with an output voltage of 1.5v because they have a 240% higher capacity for the same size.
Most cells have a rating in mAHr but when you compare a 1.5v cell with a 3.6v LITHIUM cell, the a 240% higher capacity is a bonus.
12v RECHARGEABLE batteries are measured in A-Hr - such 1.2AHr or 4Ahr.
Automobile batteries are measured in "cold-crank amps." This is a vague term like "I can do "20 push-ups in one minute." It doesn't tell you how big and strong I am. The cold-crank amps has a

weak connection to the amp-Hr capacity of the battery and how well-made it is.
A battery that can deliver a **HIGH CURRENT** is said to have a **LOW INTERNAL IMPEDANCE**. **IMPEDANCE** is another word for **RESISTANCE.** Resistance can be measured with an **OHM-METER** whereas IMPEDANCE will have the same numeric value but cannot be measured with an Ohm-meter. It has to be worked out via Ohm's Law.

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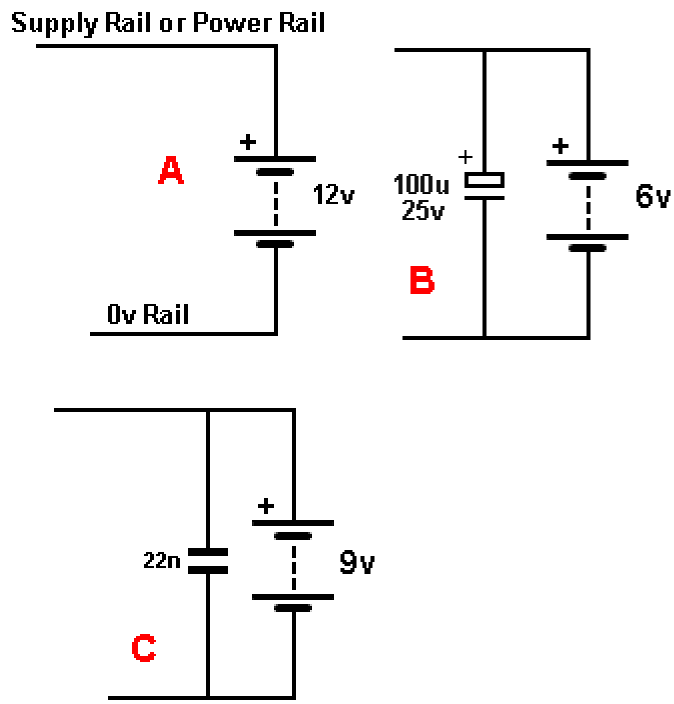

Fig 3. A BATTERY POWER SUPPLY

In simple terms, the electrolytic or capacitor improves the performance of the battery by "tightening up" the power rails (by reducing the impedance of the rails.)

A Battery **POWER SUPPLY** is shown in Fig **A**.
The top rail is called the **Supply Rail** and the lower rail is called the **0v rail**.
A battery supplies a DC voltage but as it gets "used" the voltage "dips" when a high current is needed.
This can create distortion in audio equipment and to solve this problem an electrolytic is placed across the rails.
The electrolytic is just like a miniature rechargeable battery and will supply current during the peaks of demand. See Fig **B**.
If the project is a high frequency circuit such as a transmitter (100MHz) the capacitor across the rails needs to be 22n as shown in Fig **C**.

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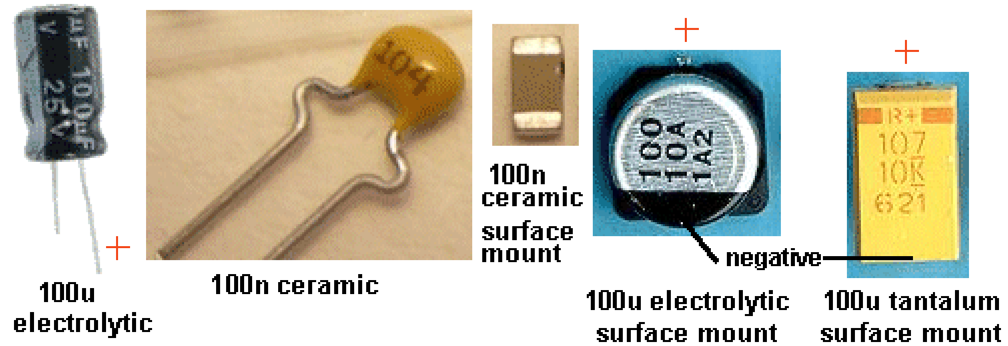
DECOUPLING CAPACITORS

The capacitor (or electrolytic) across the power rails stops the rail voltage dropping when a high current is required.
It "electrically" joins the **power rail** to the **0v rail** and this is very important in high frequency circuits such as transmitters, because the oscillator needs to "push against" the power rail to push the signal out the antenna.
A 22n across the battery improves the output considerably.
Quite often a 100n capacitor is added to each transistor stage (or IC) in a large project to prevent signals from one IC passing to another IC. In other words, the 100n ceramic capacitors prevent unwanted signals "coupling" one stage to another.
This is why the capacitors are called **DECOUPLING CAPACITORS**. They "decouple" or reduce the unwanted "spiky" signals.
When a capacitor is used to **join** one stage to another, it is called a **COUPLING CAPACITOR** and we need to separate the two terms.
The size of the capacitor depends on the frequency at which the circuit is operating and the current taken by the circuit.
The photos below show decoupling capacitors:



Surface-mount markings: 104 = 100n, 105 = 1u, 106 = 10u, 107 = 100u

Fig 4. DECOUPLING CAPACITORS

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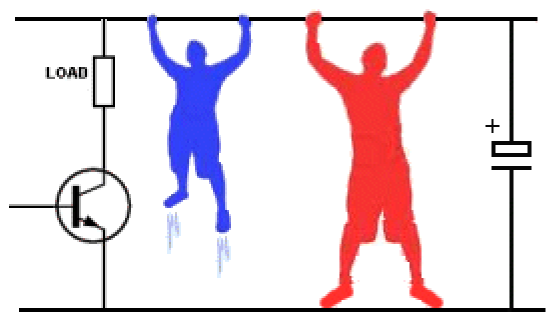

HOW THE CAPACITOR WORKS

The capacitor (or electrolytic) across the power rails rails works just like the two men in the drawing.
The first man is bouncing on the **Power Rail** just like the transistor is drawing a varying current and moving the rail up and down. The second man (the electrolytic) is holding the **Power Rail** steady.

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Whenever you get a fault in project such as distortion, or LEDs not blinking at the right time or "funny effects," the first thing you do is add an electrolytic across the power rails.
That's because the impedance of the battery or power supply might be letting pulses from one section of the circuit get into another section and upset the operation. These pulses are short, sharp and very hard to detect but an electrolytic will solve the problem.
When a battery gets "old" the supply rail gets "very floppy" and that's when a lot of problems start to show.
The reason is the impedance (the resistance) of the battery starts to increase and the **Supply Rail** is not "tied" to the **0v rail**. That's what the electrolytic does. It effectively "ties" the **Power Rail** to the **0v rail**. This fact has never been mentioned before in any text book. It's most important when you start to work with high-frequency circuits as the power rail must be kept "rigid" and the only way to do this is to place a capacitor between the rails.

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THE MAINS

For a project needing a long-term **POWER SUPPLY** or a **HIGH CURRENT**, the energy will come from the "**MAINS.**" You don't have buy batteries and the overall cost is much less.
The "**MAINS**" is a voltage of either 120v AC or 240v AC.
It is rising and falling at a rate of 50 or 60 times per second and this is called the frequency.
Frequency is measured in Hertz, with 50Hz or 60Hz being the frequency of the Mains.
Since the voltage is rising and falling we call it ALTERNATING and because the CURRENT is the part of the Mains that provides all the work (heat) it was the most important part of the MAINS.
That's why they called the Mains, **AC (ALTERNATING CURRENT)**.
The Mains is a very dangerous voltage to deal with as the 120v AC is really a voltage that rises to 180v and then drops to minus 180v at the rate of 60 times per second.
The 240v is really a voltage 345v and then a voltage of minus 345v, rising and falling at a rate of 50 times per second.
Your body can only handle 60v to 80v and anything above that can cause instant death.
That's why building a power supply and having mains voltages present on your work desk requires extreme caution.

I have not been electrified or received a shock in any of my past 50 years because I am very careful and follow this simple rule:

Only touch any part of the circuit with one hand and do not let any other part of your body or feet touch any pipes or bare floor.
Electricity must pass **through** your body to earth or a pipe or another wire to produce "electrocution."

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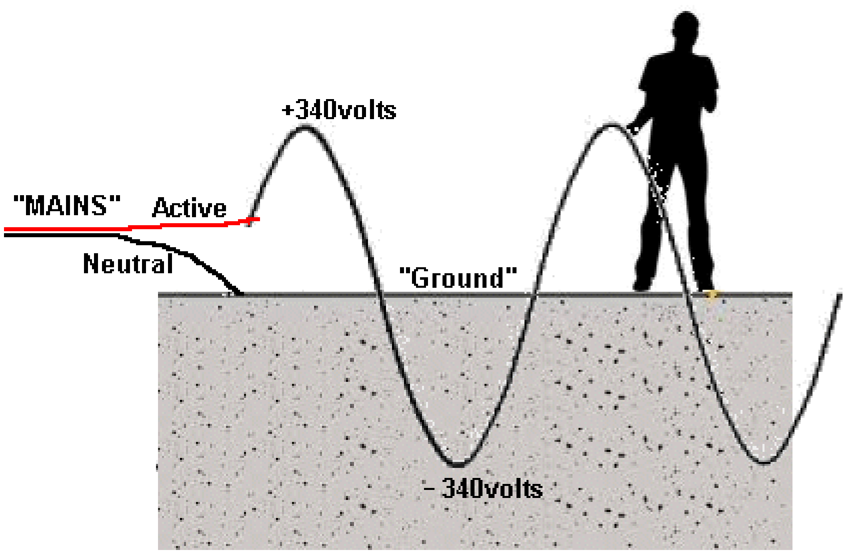

Fig 5. The "Mains" WAVEFORM

The "**MAINS**" is dangerous because the voltage is much higher than stated on any appliance.
It is actually 180v or 345v for the 240v mains.
The ACTIVE lead rises 340v then falls 340v below "ground" 50 times per second and this will produce a CURRENT FLOW through your body that will kill you very quickly.

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The EARTH

All "Mains" sockets consist of an **ACTIVE**, **NEUTRAL** and **EARTH**. This is called a 3-pin system with a 3-pin plug.
The most important connection is the EARTH because it protects you from getting a "shock."
It is important to understand the Active and Neutral carry the "electricity" (called the CURRENT) and the earth is GENERATED by driving a spike into the ground at the front of the premises.
The Active and Neutral enter a property via either overhead or underground via two separate wires or a screened wire with the ACTIVE in the middle and the NEUTRAL wound around the outside.
These two wires go back to a transformer on a lamp-post or in a sub-station where the 240v is produced by a transformer. As we know, the secondary of a transformer is not connected to any other wiring so one of the leads is connected to a wire that runs down the lamp-post to a metal rod or pole of spike driven into the ground.
This wire becomes the NEUTRAL as it will not have any voltage on it.
The other wire is called the ACTIVE and these two wires go to each home.
At the meter-box, these two wires are connected to each outlet as ACTIVE and NEUTRAL.
But suppose the wire going to the rod (called a spike) at the lamp-post gets broken.
The two wires will now be "floating" and if you touch the Neutral, you will get a tingle.
For instance, if you have a toaster and the heating element is connected to Active and Neutral, and the metal frame is not connected to anything, you will get a slight tingle if the element has a slight leakage to the frame.
This is because all the voltages are "up in the air."
Now we introduce a SAFETY wire. It is called EARTH.
At the front of the house we hammer a long spike into the ground and connect a green lead.
We take this green lead to the earth pin of all the outlets.
This wire is connected to the frame of all appliances.
Now, it does not matter if the Active and Neutral are "up in the air" because the frame of the toaster is SAFE to touch.
But the Active and Neutral are NOT UP IN THE AIR. The neural is connected to the ground via a spike at the lamp-post.
The earth spike at your house is just like a shield or screening around the other two wires so

you cannot touch either wire. You must not be able to touch either wire because someone may connect the wires incorrectly on an extension-lead and the black wire will give you a shock.

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Fig 6. A 12v WALL WART (Plug Pack)

A BASIC POWER SUPPLY

A **Basic Power Supply** consists of a transformer, rectifier and storage capacitor.
A transformer involves connecting two leads to the mains and these items can now be purchased as a sealed unit as a PLUG PACK or WALL WART, so you cannot touch the mains wires.
A Wall Wart is "so-called" because it takes over the wall socket so nothing can be fitted into the adjacent socket!!
It is suggested that a fully approved PLUG PACK be purchased to power any project in this course and use the following notes as instructional material.

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A BASIC POWER SUPPLY - Part 2

The circuit for a Basic Power Supply is shown in **Fig 7 and 10**.
The mains can be 120v or 240v and the transformer used in the project is designed for the exact voltage. You cannot use a 120v transformer on 240v or 240v transformer on 120v.
The 120v /240v is called the MAINS and it rises and falls at either 60 or 50 times per second. This frequency is called Hertz (Hz) and it produces flux (called MAGNET FLUX) in the core of the transformer.
The core is called a **MAGNETIC PATH** and the number of turns on the primary winding produces the maximum magnetic flux for the type of material used in the core.
The turns are then counted and this provides the data: TURNS PER VOLT.
If the answer is 6 turns per volt, we can wind another coil next to the PRIMARY WINDING and each 6 turns will produce 1v in the SECONDARY WINDING.
The primary winding takes up half the bobbin and the secondary winding takes up the other half.
If only a few turns are needed for the secondary, a large gauge of wire can be used.
The size of wire will give us the SECONDARY CURRENT, taking into account the heating of the transformer.
This produces 4 wires and the primary winding is separated from the secondary by a sheet of plastic.
When the primary is connected to the mains, the secondary is not PHYSICALLY connected to the mains and can be touched without getting electrocuted. It is MAGNETICALLY CONNECTED.
The transformer provides a SAFE voltage and a current (from the secondary winding) that can be used to power an electronic project.
Winding a transformer must only be done by a professional as the winding wire must not be scratched or allowed to touch the core of the transformer. The insulation between the windings must be certified and able to resist a high temperature. It must also be sealed to prevent the windings vibrating by dipping in resin and baking in an oven to set the resin.
This type of transformer can be bought as a PUG PACK or WALL WART where the primary winding is connected to pins and thus the mains is not exposed - and CANNOT BE TOUCHED.
The next component needed in a POWER SUPPLY is a rectifier.
This is a diode or set of diodes.
We have seen a diode can be used in a circuit to allow current to flow and when the battery is fitted around the other way, no current flows.
That's how it works as a **RECTIFIER**.
The mains is just like a voltage being delivered to the transformer and it starts a zero volts. The voltage increases to a maximum then decreases to zero.
We talk about one of the wires as being neutral and equal to zero volts at all times and the other wire increasing and decreasing. This wire is called the ACTIVE.
The active wire then becomes negative and its voltage falls to as much as minus 180v or 345v.
It then becomes less negative and finally reduces to zero. This is shown above with the waveform and image of a man and "ground."
A diode placed on the ACTIVE wire will allow voltage and current to flow though the diode when the voltage is "above ground" and no current (or voltage) will flow though the diode when the waveform is below ground.

This is the principle of **RECTIFICATION**.
It takes an AC voltage (a waveform) and only allows the top portion to pass through a diode.
If a diode is placed on the same waveform, in the reverse direction, only the negative portion of the waveform will be processed.

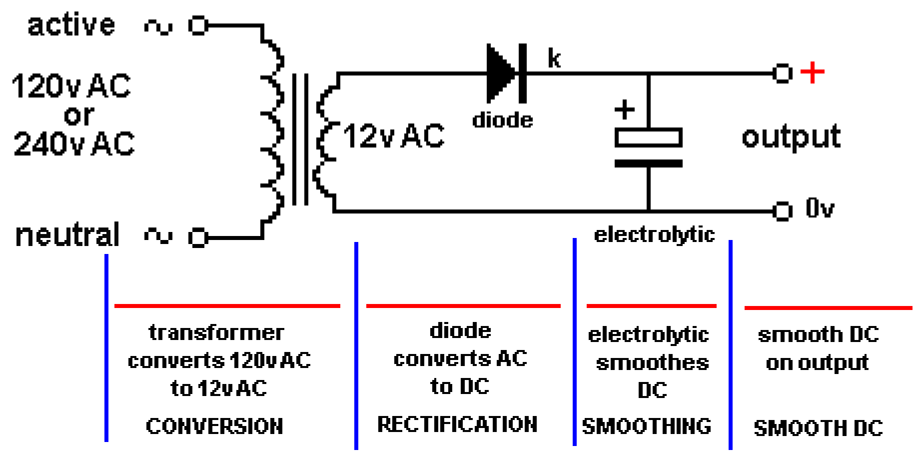

Fig 7. The MAINS POWER SUPPLY

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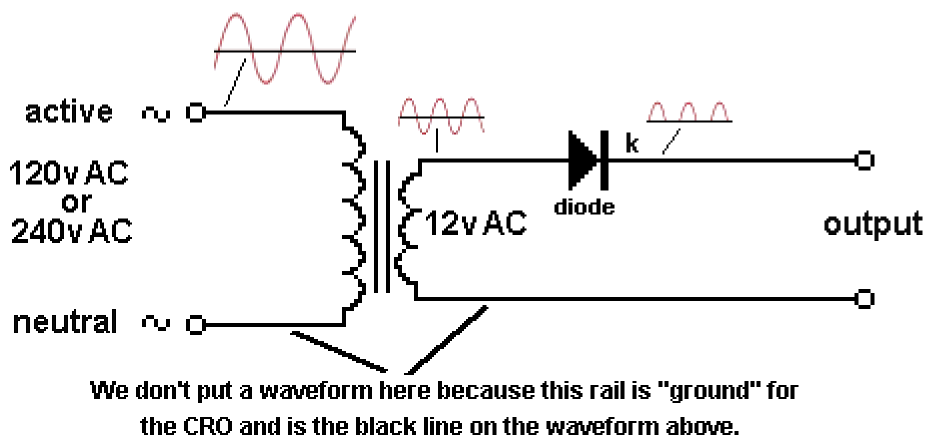

When **one diode** is used on the secondary of a transformer, the circuit is called **HALF-WAVE RECTIFICATION**.
It is called **Half Wave** because only the positive of the mains (the "rising" part of the wave - the part **above** the black line) is passed to the output of the circuit.
This is a very wasteful circuit as only half the energy is used and it also heats-up the transformer because the unused portion of the waveform leaves flux in the magnetic circuit and this flux upsets the flux generated by the next portion of the cycle.
The diagram above shows a single diode and the output it produces. The output is called **UNFILTERED DC** and is not suitable for any electronic project as it will produce buzz, hum and faulty operation of a project. It is only suitable for charging a battery.

Fig 8. HALF-WAVE RECTIFICATION

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By adding more diodes we can pass both the positive and negative portions of the secondary to our circuit and get a waveforms as shown in the diagram below.
This waveform cannot be used in any electronic equipment as it will produce a lot of background "hum."
In the next frame we will show how to improve the waveform.
The 4 diodes in the rectifier are called a **BRIDGE**.
The animation below shows how two diodes pass the positive waveform to the output and then the other two diodes pass the negative portion of the waveform.
We have removed the two diodes that are not active during each portion of the cycle to show how the other two diodes work.

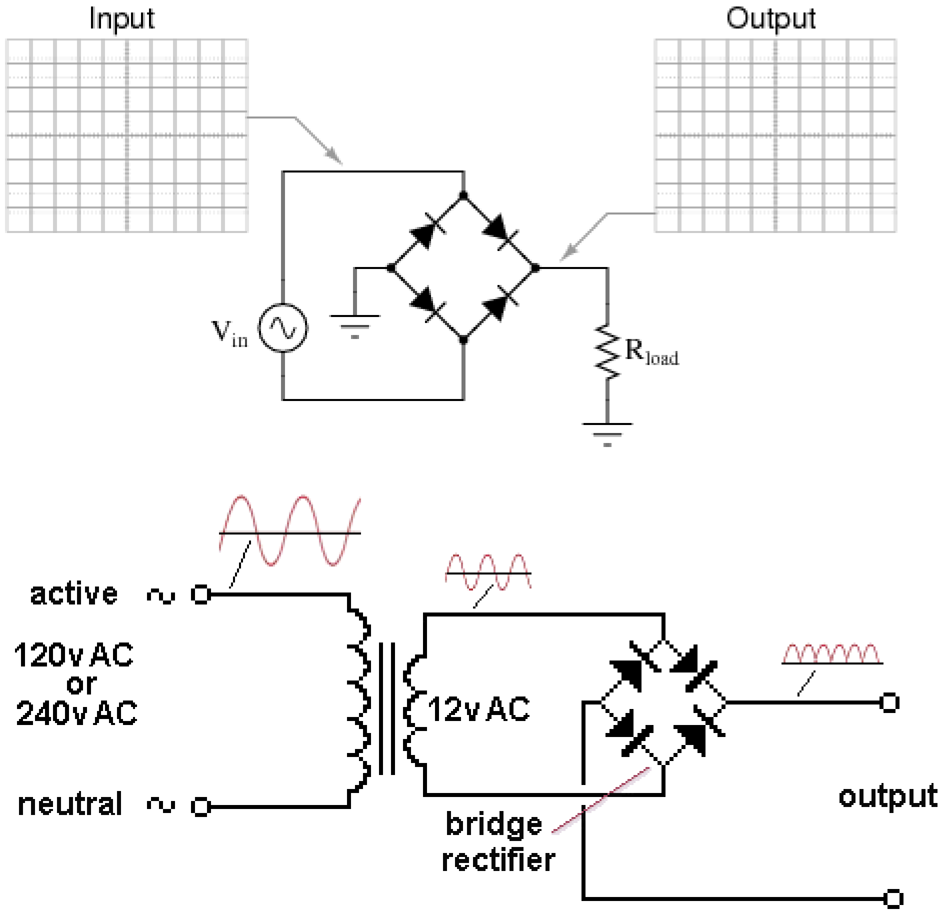

Fig 9. FULL-WAVE RECTIFICATION

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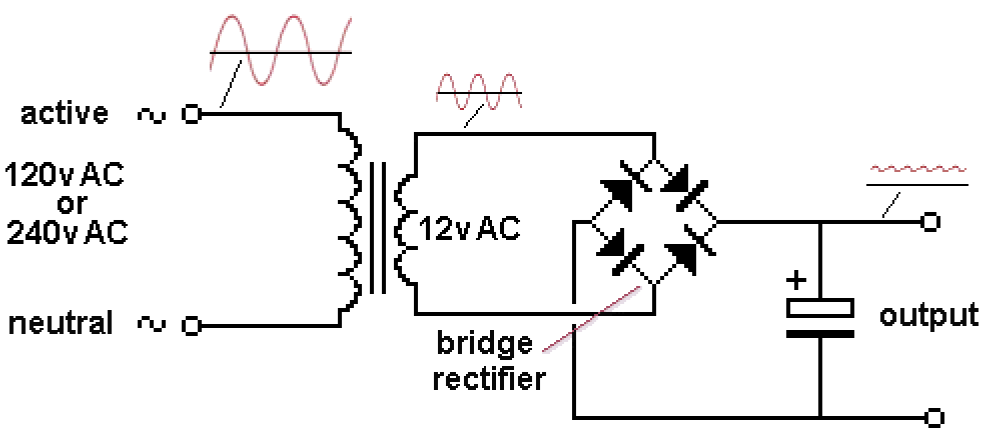

The output needs to be **FILTERED** or **SMOOTHED** so the voltage can be connected to a piece of equipment.
The filtering is done with an electrolytic.
An electrolytic is like a rechargeable battery.
It gets charged when the voltage is high and delivers some of its energy when the voltage is low.
The result is a much smoother output.
The circuit above is inside a **PLUG PACK** (**WALL WART**)
The normal value for the filtering electrolytic is 1,000u for up to 1Amp supply.
We are not going into any mathematics to calculate this, however the formula is:

$$V_{\mathrm{PP}} = \frac{I}{2fC}$$

where Vpp is the ripple voltage produced after a bridge rectifier when current $\mathbf{I}$ flows (1amp) and f is the frequency (100Hz or 120Hz) and C is 0.001Farad (1,000u). **Answer = 5v**.
Any voltage above 100mV is noticeable in an amplifier and that's why a plug pack is not suitable

for powering an amplifier. You need **additional** filtering in the form of a **regulator**.

Fig 10. FILTERING THE OUTPUT

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IMPROVING THE OUTPUT

Both the voltage and the ripple of the Power Supply above is not very good.
It is not good enough for modern equipment.
Most transformers produce a voltage higher than shown on the label and it can be as much as 5v too high.
In addition, the output has a ripple (as high as 5v p-p when drawing 1 amp) and this is noticeable in an amplifier.
This means the output can he higher than required (as some plug packs are 5v higher than the specified voltage of say 12v) and it can be "noisy" (the ripple increases when the current-demand is increased).
These two problems can be fixed with a **REGULATOR**.
This is a chip containing many transistors and components that electronically remove the ripple and produces a steady output voltage. (Steady means: FIXED and very low ripple).
These regulators are commonly called **3-TERMINAL REGULATORS** and look like a power transistor (also called **LINEAR REGULATORS**).

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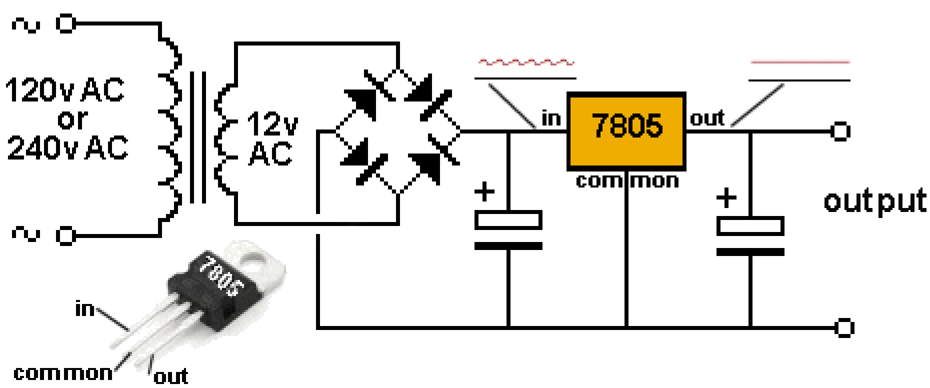

3-Terminal Regulators come in a range of fixed voltages and most are capable of handling 1 amp, provided they are correctly heatsinked so they do not get so hot you cannot touch them.
A 3-terminal regulator will will simply allow you to use the voltage that starts at 0v and rises to a voltage where the ripple begins. Suppose the ripple begins at 8v, the 7805 has a voltage-drop across the IC of 3v and this will allow an output of 5v.
As we have mentioned above, the ripple will be at 8v plus 10v when the current is zero and the ripple will, increase as current is drawn.
The electrolytic before the regulator removes most of the ripple from the rectifier (leaving 5v ripple when 1 amp flows) and it should be about 1,000u for each 1 amp needed in the output.
The electrolytic after the regulator prevents the regulator oscillating. It should be about 10u. A 100n can also be added before and after the regulator to prevent it oscillating.
Adjustable Regulators (such as **LM 317**) can be adjusted from 1.2v to about 35v and will deliver 1.5Amp. See Fig 14.

Fig 11. ADDING A 3-TERMINAL REGULATOR

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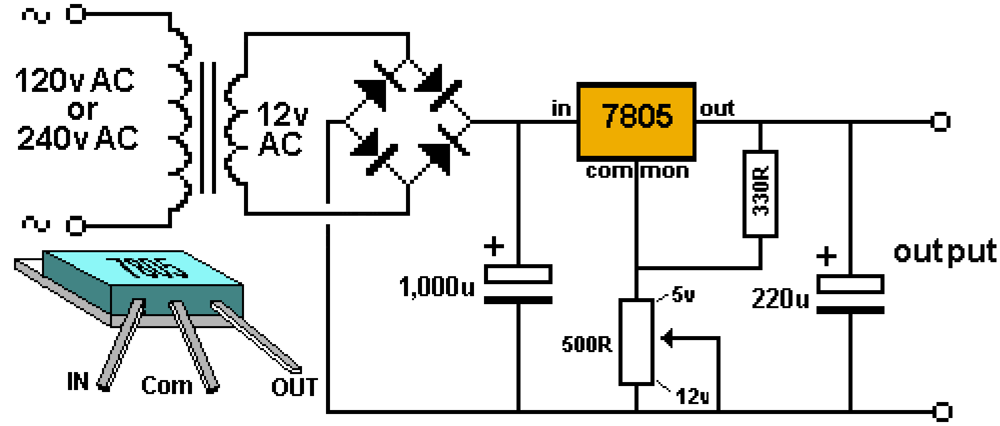

The voltage of a 3-terminal regulator can be increased by putting a voltage-divider on the **COMMON** terminal. This increases the voltage on the common terminal and the output of the regulator is 5v higher than this value (if the regulator is a 5v component).
If the regulator is a 12v device, the output is 12v higher than the common terminal. This is called "**JACKING-UP**" a 3-TERMINAL REGULATOR.
7805 devices are 1 amp. 78M05 devices are 500mA !! Be careful !!!! They are really "failed" one-amp devices!!
The 78xx range of regulators are called **POSITIVE REGULATORS**
79xx are **NEGATIVE REGULATORS** - they have a different pin-out, so be careful.

Fig 12. "JACKING-UP" A 3-TERMINAL REGULATOR

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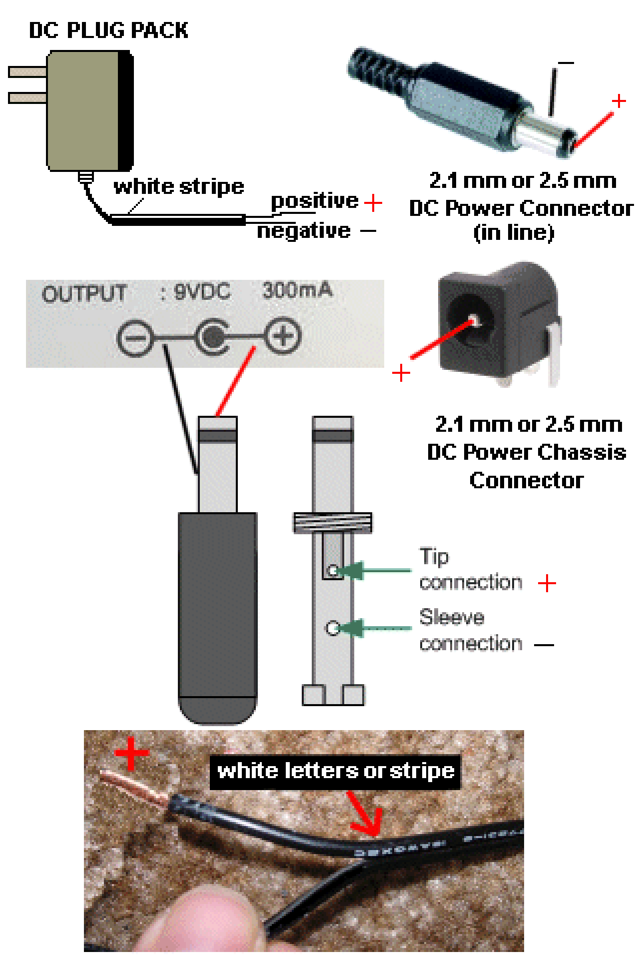

Fig 13. PLUG PACK POWER SUPPLY

PLUG PACK POWER SUPPLY

The simplest power supply is a **PLUG PACK** (WALL WART).
See **Fig 10** above for the circuit inside a Plug Pack.
It is **sealed** and safe and low-cost.
They are available in a wide range of voltages, current-ratings (300mA, 500mA and 1 amp) and some are AC output.
Most Plug Packs are **DC** and some are switchable from 4.5v DC to 12v DC.
Some have bare wires and some have a 2.1mm or 2.5mm "in-line" Power Connector with the TIP POSITIVE.
Some have a removable plug to make the TIP NEGATIVE.
The white stripe on the lead indicates the positive wire.

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PLUG PACK POWER SUPPLY

DC Plug Packs contain a transformer, bridge rectifier and an electrolytic. The circuit for this is shown in **Fig 10** above.
This type of Power Supply is called **UNREGULATED**. This means the output voltage is not fixed and will normally be 3v to 6v HIGHER than the voltage stated on the case.
The reason for this is as follows:
The windings of the transformer have a small resistance and when it supplies a CURRENT to the device you are powering, the voltage drops a small amount.
To allow for this voltage-drop, extra turns are added to the secondary so the output voltage is 3v-6v HIGHER than stated on the label and when the FULL CURRENT is drawn, the voltage drops to the specified value.
The voltage is also higher so that the ripple (as high as 5v) will be "on top of" the 12v so the output will be a genuine 12v with some ripple "on top of" the voltage. The ripple will be 5v when 500mA flows.
This is one of the problems with a Plug Pack and is called REGULATION.
Plug Packs have very poor **VOLTAGE REGULATION**.
Poor **Voltage Regulation** means the voltage starts at say 17v and drops to 12v when a load is applied.
A **Switch-Mode Power Supply** does not have this problem. The output is regulated and the voltage is FIXED over the range 1mA to more than 1 Amp.

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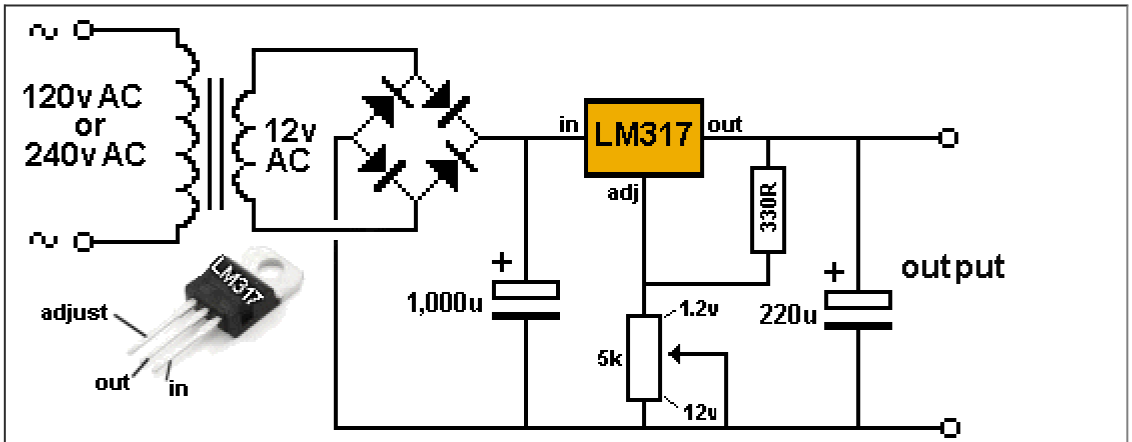

Adjustable 3-terminal regulators are available and they can be adjusted from 1.2v to about 37v. These regulators have a current-capability of 1.5 amp, providing they are heatsinked and the temperature of the device does not rise above 105°C.
LM317T and LM317 are identical. The plastic package is slightly different in shape.

Fig 14. ADJUSTABLE 3-TERMINAL REGULATOR

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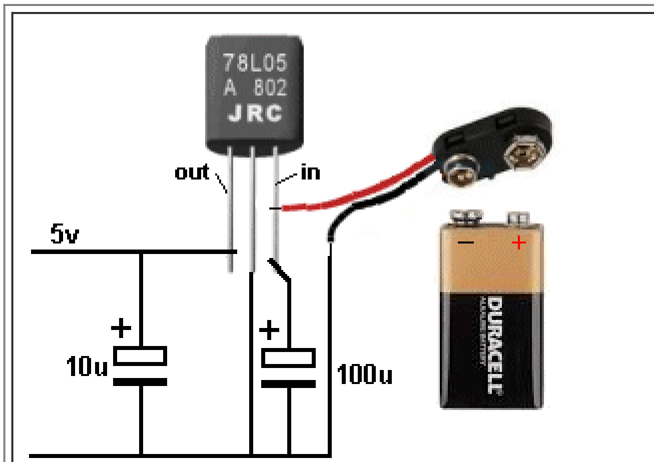

Fig 15. 100mA 5v POWER SUPPLY

When using a regulator, there are two things you have

A 100mA regulator can be used to produce a 5v regulated power supply from a 9v battery.

The 78L05 takes 3mA to 5mA to operate the internal circuitry and the minimum input voltage is 7v.
A 9v alkaline cell will supply 25mA (plus 5mA for the regulator) to a load for 15 hours. At this point the voltage of the battery will reach 7v and the regulator will "fall out of regulation." The 5v rail will drop to 4.75v, 4.5v etc. However the circuit will deliver up to 100mA for short periods of time with a fresh battery.
A switch is needed on the battery as the regulator takes 3mA to 5mA when

to remember.
The regulator needs about 3v to 4v across it to drive the circuitry inside it and it takes 3ma to 10mA. This means the battery voltage needs to be about 6v higher than the output of the regulator so the battery voltage can fall and the circuit will still work perfectly. A 9v battery will only just be ok.

it is working and you cannot leave it connected as the battery will eventually go flat.
There are some regulators that drop only about 1v across them. They are called LOW-DROPOUT. You need to look up their part number.

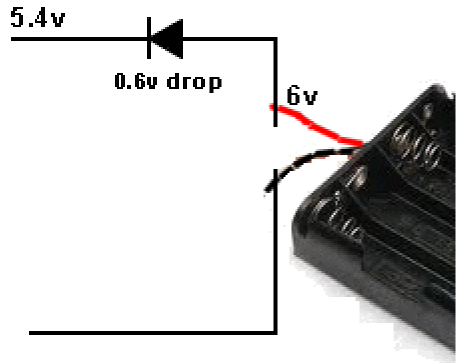

Fig 15a. Another 5v POWER SUPPLY

Many chips and microcontrollers require a 5v supply and it must not go higher than 5.5v.
By using four 1.5v cells and a power diode in the positive rail, a 5.4v supply can be created.
The circuit relies on the fact that the power diode will drop 0.6v to produce 5.4v for the project.
This is a very handy feature for battery-operated equipment and the battery-pack must not be higher than 6v.
(Any silicon diode will drop 0.6v. A Schottky diode will drop 0.3v).

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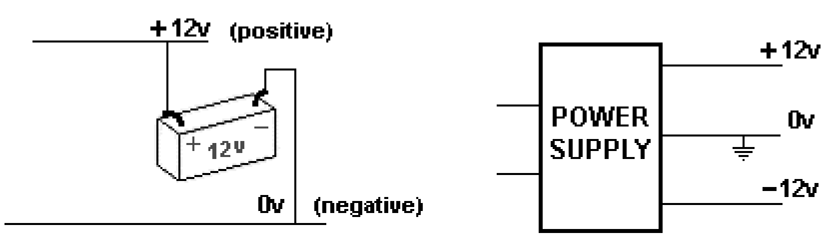

Sometimes you will see a circuit as shown in the **first diagram** with 12v or +12v on the top rail and 0v or a negative sign or the word "negative" on the bottom rail. In **this case** the word negative means earth or "chassis of a car" and we commonly refer to this as "negative earth" or "negative chassis" and we really mean "0v chassis."
In the **second diagram**, the output from a power supply has a positive 12 volts and a negative 12v with the 0v rail in the middle. In **this case** the negative 12v rail is twelve volts BELOW the earth rail and that's why we call it the NEGATIVE RAIL.
This means that when you see "Negative Rail," you need to work out if it means the negative terminal of a battery (as in the first case - meaning 0v or earth) or if the voltage is below zero volts (as in the second case).

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VOLTAGE AND CURRENT

A power supply will deliver two things.
It will deliver a VOLTAGE and it will deliver a CURRENT.
Voltage is the tingle you get on your tongue when you touch a 9v battery.
Current is the heat you feel when you put a resistor across the terminals of a 9v battery.
An **OPEN CIRCUIT** is a switch that is not pressed.
A **CLOSED CIRCUIT** is a switch that is pressed and the normal current flows.
A **SHORT CIRCUIT** is a fault in a circuit and **EXCESS CURRENT** flows. One or more components may get very hot or "burn out" or the plastic on the wiring may "start to smoke."
A **SHORT CIRCUIT** is generally two wires touching or components touching each other and the voltage flows through components that have a very low resistance. Because the resistance is very LOW, a **LARGE CURRENT** flows.
Some batteries (such as alkaline cells), rechargeable batteries (and cells) and some power supplies can deliver a **HIGH CURRENT** when components touch each other and this can destroy them. When you are experimenting and designing a project, it is good idea to use DRY CELLS as they can only deliver a small current if a fault develops.

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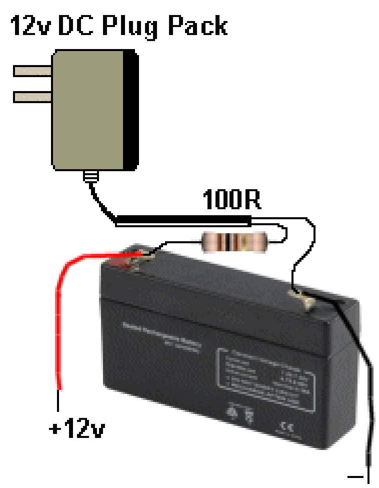

Fig 16. BENCH POWER SUPPLY

This Power Supply will deliver a **VERY HIGH CURRENT** so be careful to avoid any **SHORT CIRCUITS**.
You can use 2, 3, 4 or more rechargeable cells in place of the 12v battery.

BENCH POWER SUPPLY

A power supply on your work-bench is called a **BENCH SUPPLY** and it can be anything from a set of cells to a very expensive adjustable POWER SUPPLY.
We mentioned above the problem with a Power Supply that can deliver a HIGH CURRENT.
Your project can "go up in smoke" if a short-circuit is present.
That's why it is best to use cheap dry cells and avoid the possibility of destroying anything.
However if you want a cheap **Power Supply** capable of delivering a HIGH CURRENT, here is a low-cost **BENCH POWER SUPPLY**.
It uses a 1.2AHr rechargeable battery and a 12v DC plug-pack to keep it charged. All you need is a 100 ohm 0.5watt resistor in the positive lead to keep the charging current below 50mA and the battery will never get overcharged and it will be ready for all occasions.

Question from a reader: What happens if I charge a battery with too little current?

A rechargeable battery loses its charge at the rate of about 10mA to 50mA ALL THE TIME.
Eventually it is FLAT and will not illuminate a globe.
To prevent this happening, the battery can be charged at 10mA to 50mA via a resistor shown in Fig 16.
This means the battery will remain fully charged AT ALL TIMES and is ideal for emergency situations.
If you charge a battery with less than 10mA, it will eventually go FLAT and it may take slightly more than 50mA to keep a large (high AMP-HOUR) battery fully charged.
Charging a battery with a low current will just take longer to achieve FULL CHARGE and no damage will occur.
In fact it will prevent salt formation occurring and lengthen the life of the battery considerably.

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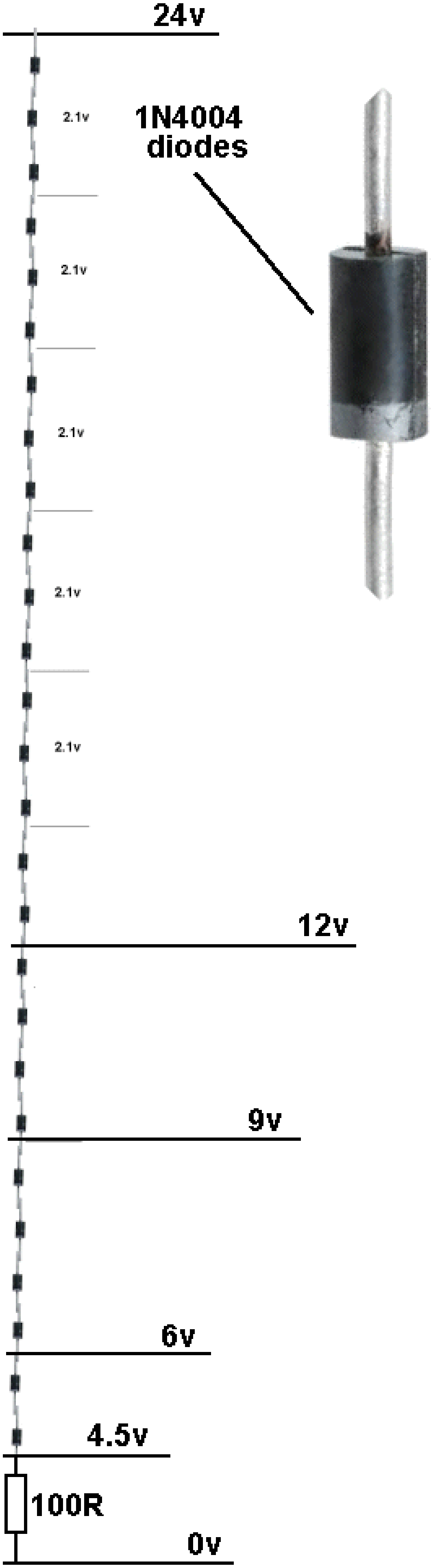
ANOTHER POWER SUPPLY

Here is a request from a reader.
He wanted 12v, 9v, 6v and 4.5v from 24v at 0.5 amp.
Maybe he has a truck with 24v system.
This project will work for many different requirements.
Use 1 amp diodes for 0.5amp loads and 3 amp diodes for 2 amp loads.
Make sure you include a 1 amp or 3 amp fuse, otherwise the diodes will go up in smoke if you short the output or take excess current.
This is just one solution. Diodes are very cheap and can be bought for $2.00 per hundred.
Just twist the leads around each other and solder them. Keep the leads long to dissipate the heat.
You can add small heatsinks made from the lid of a steel tin can and soldered to the leads for the 3 amp version.   Make sure nothing touches the heat-fins.
Each diode will drop 0.7v when 0.5 amp flows. And when 0.7A flows through a 1 amp diode, the voltage drop will be 0.9v.
This means the output voltage will not be stable or reliable. It is just a simple way to get a lower voltage from a 24v battery (or 12v battery).
About 0.25 watt to 0.5 watt (of heat) will be dissipated from each diode and this will make them quite hot when they are all connected together.
The voltage drop across a 1 amp diode when 1 amp is flowing will be 1.1v and the output voltage will be much less than expected. That's why 700mA is the maximum for this project.
Here is the circuit:


24v
2.1v
1N4004
diodes
2.1v
2.1v
2.1v
2.1v
12v
9v
6v
4.5v
100R
0v

The 100R is just to keep the diodes "in conduction" so they are passing a small current. Connect between the 0v rail and one of the voltages to get the desired voltage.

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BOOSTER PACK

Here is another form of **POWER SUPPLY.**
It is called a **BOOSTER PACK** and is designed to start a car when the battery is slightly flat.
Here's how and why it works.
When a car battery goes "flat" some or more of the energy has been released to lighting a globe such as when the headlights have been left ON.
This causes the conductivity of the sulphuric acid to increase and it will not deliver a high current.
If you try to start the car, slightly more voltage is dropped across the acid and the terminal voltage drops to as low as 8v.
Under normal conditions, the starter motor takes 300 amps and this is when the battery voltage is 12v.
When it drops to 8v, the current drops to 200 amps max and the wattage drops from above 3600watts to less than 1600 watts.
The result is the starter-motor will not turn over the motor.
The current reduces, not because the battery cannot supply the current but because the voltage is lower and Ohms Law does not allow a higher current to flow.
Enter the BOOSTER PACK.
It consists of a battery with a small amp-hour capacity BUT with a terminal voltage of 12v.
When it is put across the car battery, two things happen.
The voltage of the car battery increases to 12v because it is being charged.
And secondly the car battery receives a small amount of energy during the charging process.
The booster battery can really only supply about 100 amps for the small version and about 200 to 300 amps for the larger version.
But this is enough to add to the capability of the car battery and provide the 12v which is the necessary part of starting the car.
When 12v is present, the starter motor will take 300 amps and deliver the power needed to turn the motor over.
The secret is providing and maintaining the 12v.
Both the small, medium and large Booster Packs will work.
Obviously a big pack will be needed for a big car with a really flat battery.

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Now that you have learnt about the POWER SUPPLY and possibly built one for your work-bench, you will want to know how to use it.

VOLTS AND AMPS

The two values (called UNITS) we need to measure are **VOLTS** and **AMPS**.

VOLTS are normally measured in values from 1volt to many thousands of volts but when the voltage is less than 1v, we use the term **millivolt**. 1,000millivolt = 1volt
We can also write: 2,500millivolt = 2.5v or 2,500mV = 2v5 These are the same reading.

We also need to measure **CURRENT**. Current is measured in **AMPS**. For most electronic work we measure the sub-multiple: "milliamp." 1,000 milliamp = 1 amp.
We can also write 2,500mA = 2.5A

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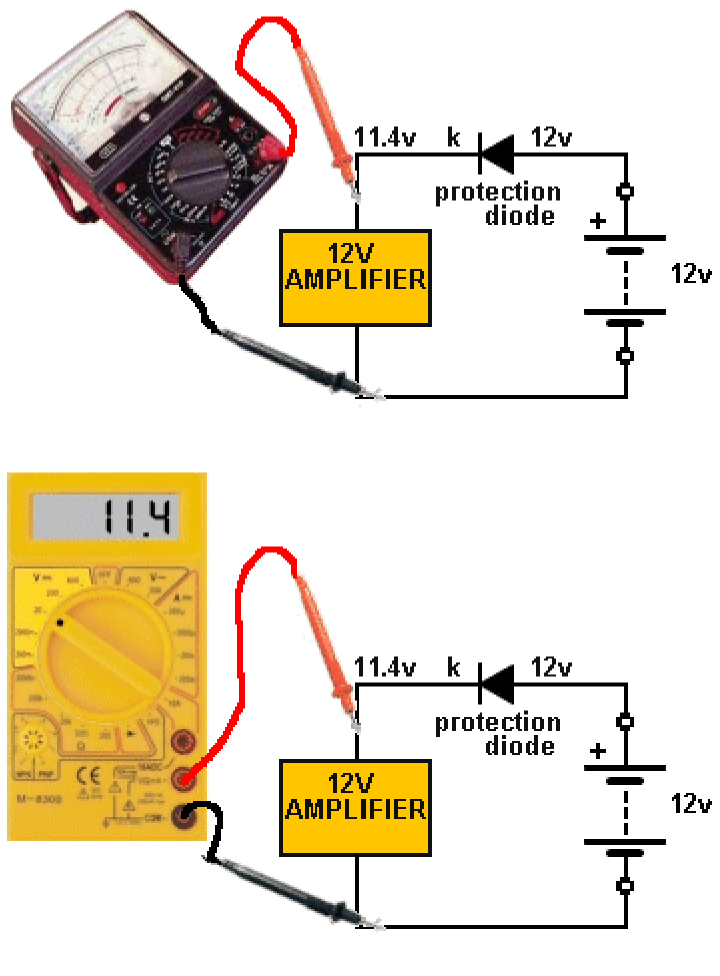

Fig 17. Measuring Voltage

MEASURING VOLTAGE

To measure **VOLTAGE** you need a **VOLTMETER**.
A Voltmeter is available on all **MULTIMETERS**.
It is one of the **RANGES**.
It is identified by the letter "**V**" or "**mV**"
There are two types of **MULTIMETER**:
ANALOGUE and **DIGITAL**.
Analogue Multimeters have a needle and must be connected around the correct way to make the needle swing "up-scale."
The red probe connects to the positive side of the component you are measuring and the black probe connects to the negative side.

Digital Multimeters have a screen and can be connected either way around. The screen will produce "-" if the probes are connected around the wrong way.

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MEASURING CURRENT

To measure **CURRENT** you need an **AMMETER**.
An Ammeter is available on all **MULTIMETERS**.
It is one of the **RANGES** identified by the letter "**A**" or "**mA**"
To measure 1 amp or more you need to select the 10AMP range.
Current is measured by "breaking into the circuit" and inserting the probes so the positive probe (red probe) is closest to the positive of the battery.

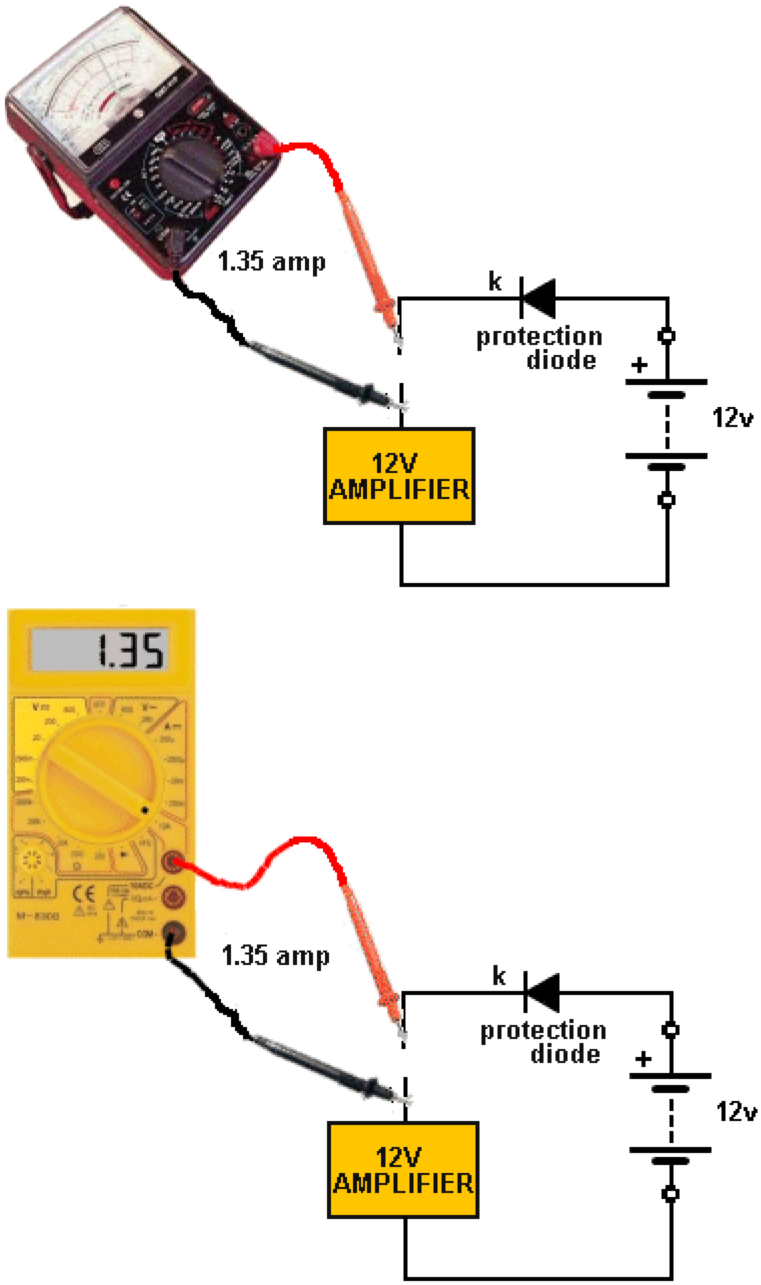

Fig 18. Measuring Current

The black probe is connected to the other side of the "cut."
Do not put the probes directly across the battery as this will cause a large current to flow through the multimeter and either "blow the fuse" in the multimeter or overheat the leads.

A multimeter on a CURRENT SCALE is classified as a "LOW RESISTANCE DEVICE" (or piece of test equipment) and acts just like a "**SHORT CIRCUIT**." That's why it can only be placed in series. If placed across a battery, it will act like a **SHORT-CIRCUIT** and be **DAMAGED**.

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Suppose your multimeter only has a current reading to 500mA and you need 1amp.
You can make your own **0 - 1amp** scale by connecting 4 resistors in parallel.
Use 3 x 3R9 and 1 x 4R7 in parallel to produce a single 1 ohm resistor with a rating of 1 watt (if each resistor is 0.25watt).
Place this resistor in the positive rail and connect your multimeter across it by selecting the 0v - 2.5v scale.
The 0v to 2.5v scale will now be: 0Amp to 2.5 amp (0mA to 2,500mA).
The resistors will get very hot above 1amp so you have to take very brief

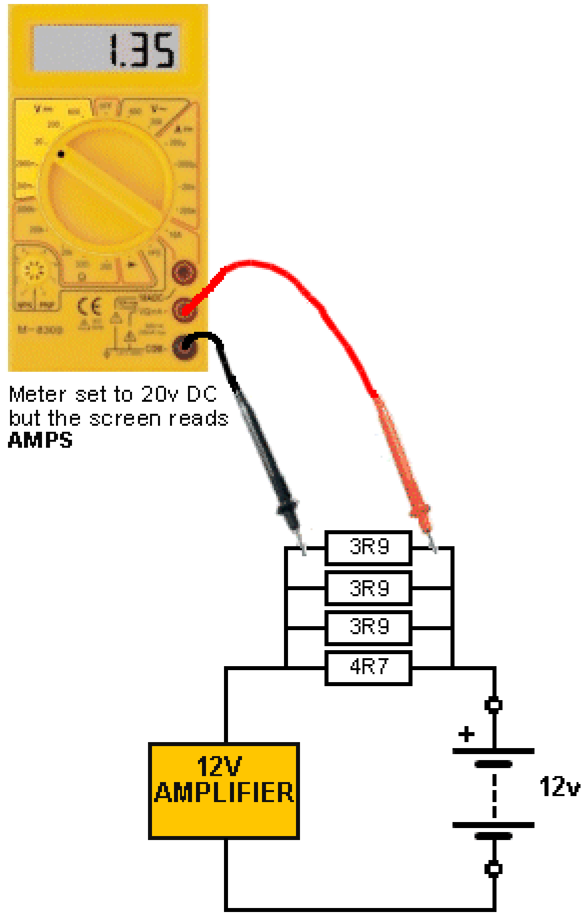

Fig 19. Making an AMMETER

readings.

Some circuits fail to work when an ammeter is connected in the normal way and the arrangement we have suggested with the 4 resistors will fix the problem. It introduces a much-lower impedance to the circuit.
The leads of the meter are not included in the circuit and when the project is operating at high frequency, the leads don't form an additional impedance to upset the current-reading on the meter.

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Some QUESTIONS ANSWERED:

A project requires 100mA but the **Power Supply** will deliver 1Amp. Will this "burn out" my project?
If the **Power Supply** is 12v and the project requires 12v, the project will take 100ma and NOT burn out.
You can connect a 12v device that takes 10mA and it will take exactly 10mA. The project determines the current-flow (providing the voltages are correct).
What happens if I connect a **Power Supply** to my project "around the wrong way?"
Some projects will be damaged. That's why you use "dry cells" for a Power Supply as the small current they will deliver will not damage the project.
What happens if I connect a 12v Power Supply to a 6v project.
Most projects will take a **LOT MORE** current when the voltage is higher than specified. The "over and under" voltage should NOT be more than 1v to 2v.
What will happen if I connect my 12v 1amp **Power Supply** to a project that needs 2Amp?
The project will work and not be damaged. It will not produce full brightness or full volume and the input voltage will possibly be 10v to 11v, due to the project OVERLOADING the power supply.
I can hear "hum" in the background of my amplifier.
The **Power Supply** does not have enough smoothing. Try a battery
Can I connect my 12v **Power Supply** in series with a 12v battery to get 24volts? Yes.
Can I connect my 12v Power Supply to a 12v battery to charge it?
A 12v battery needs over 15v and a 100 ohm resistor in series to charge it. A 12v Power Supply will not provide sufficient voltage.
How can I make a 5v and 9v Power Supply?
The easiest and cheapest way is to use dry cells. Or you can build a circuit using an adjustable 3-terminal regulator. It is not a good idea to put a resistor in the positive lead of a 12v supply to drop the voltage as you don't know the exact current that will flow and the voltage may be higher or lower than expected.
The voltage of my 12v supply drops to 10v when I connect my project.
The current-flow is more than the supply will deliver. We mentioned above that the transformer

windings have a small resistance and the voltage is being dropped across the secondary winding when a current flows. Build the simple **Bench Power Supply** shown in **Fig 16** above. A good Power Supply is classified as a **LOW IMPEDANCE DEVICE** and the concept of charging a battery and using it to deliver the voltage and current will produce a **VERY LOW IMPEDANCE POWER SUPPLY**. In other words we are producing a power supply capable of delivering a **HIGH CURRENT**.

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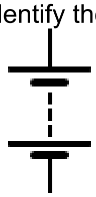
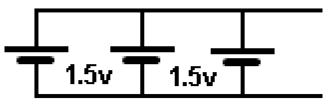
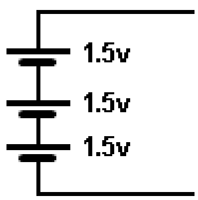
POWER SUPPLY TEST - 1

1. Why are cells placed in SERIES?
2. What is the voltage when 6 dry cells are placed in SERIES?
3. Identify the positive of the battery symbol:

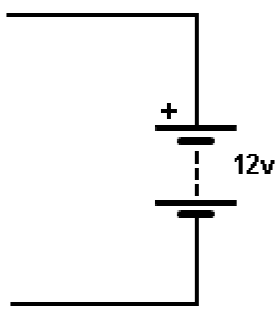


4. A battery will deliver VOLTAGE and ____________
5. What is the output voltage of these:

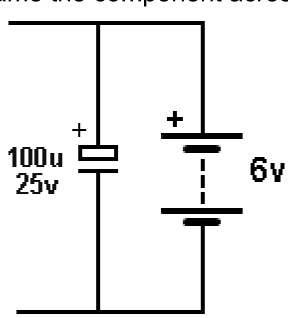




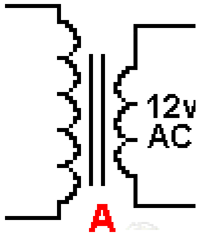
6. Can you connect two 9v batteries in SERIES?
7. Name the top and bottom rails:

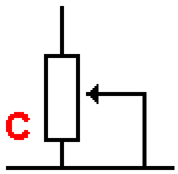


8. Name the component across the rails:



9. Name these components:





10. What is the purpose of putting an electrolytic across the power rails?
11. Name the three sections of a simple mains power supply:

____

____

____

12. A bridge rectifier in a power supply produces a half-wave supply or full-wave supply?

13. When does the highest current flow:
A. OPEN CIRCUIT B. SHORT CIRCUIT C. CLOSED CIRCUIT

14. What do the letters "**AC**" stand for?
15. Should a battery have a **HIGH INTERNAL IMPEDANCE** or **LOW INTERNAL IMPEDANCE**?
16. The voltage of a battery can be measured with a Multimeter set to ________ range.

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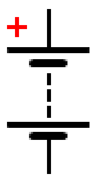
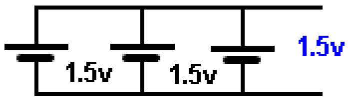
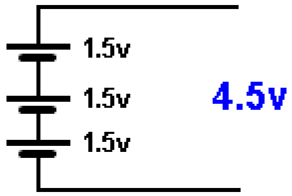
POWER SUPPLY TEST - 1 ANSWERS

1. To increase the output VOLTAGE
2. 9v
3.

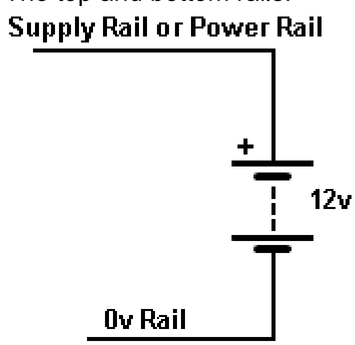


4. A battery will deliver VOLTAGE and CURRENT
5. The output voltage:

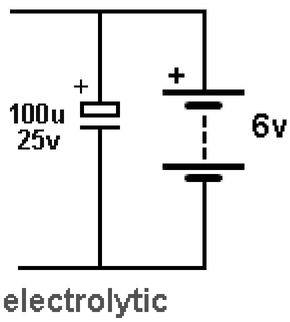




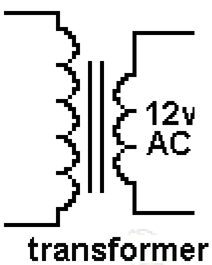
6. Two 9v batteries in SERIES produces 18v battery
7. The top and bottom rails:

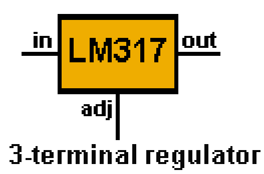


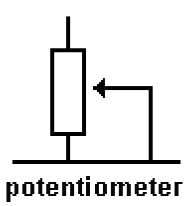
8. The component across the rails:



9. These components:







10. An electrolytic across the power rails will reduce ripple, spikes, distortion, reduce noise from one section entering another section, "tighten up the rails," reduce the impedance of

the battery.
11. transformer, rectifier, filter
12. A bridge rectifier in a power supply produces a full-wave supply.
13. SHORT CIRCUIT
14. "**AC**" = Alternating Current
15. A battery should have a **LOW INTERNAL IMPEDANCE**
16. The voltage of a battery can be measured with a Multimeter set to "**V**" (volts) range.

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RECAPPING

Whenever you are dealing with a **Power Supply** or **Power Rails**, you are dealing with a **LOW IMPEDANCE CIRCUIT**.
A **Low Impedance Circuit** does not rise and fall when the current increases and decreases.
It does not allow spikes from one part of a circuit to be transferred to another section.
And it is capable of delivering a HIGH CURRENT.
There are many ways to produce a Low Impedance Circuit and the simplest is to add capacitors (electrolytics).
Other methods of keeping the rails "**tight**" include using thick wire for the leads, wide traces on a printed circuit board and keeping the traces (printed wiring) as short as possible.
If a problem still exists, replace the supply with a set of rechargeable cells and shorten the leads to the battery. Remove plugs, sockets and switches during the test and don't monitor the current as the leads of the multimeter will introduce a lot of extra impedance.
This is especially important in high-frequency circuits as the power-rail is acting as an unwanted radiator for the signals and if these are long and thin, more of the signal gets radiated to the air and is lost. You only have to increase the leads to the battery on a 100MHz transmitter by 3cm and the output falls by 50%.
When measuring the current of a fly-back oscillator that is illuminating a LED, the illumination will drop due to the added impedance of the multimeter leads.
These examples show how a short "track" "trace" or "lead" will have a very big effect on the impedance of a circuit.

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The power supplies we have covered in the circuits above are the best and cheapest.
Many Basic Electronics Courses go into far too much detail on Power Supplies. The chances of using a simple Linear Power Supply in a project is remote.
Linear Power Supplies are very expensive, large, wasteful, designs and the more-compact **S**witch-**M**ode **P**ower **S**upply is cheaper, lighter, higher-current and much more efficient.
The output of a **Plug Pack** has up to 5v ripple whereas a **SMPS** has less than 50mV.
However there are some **BUILDING BLOCKS** associated with power supplies that can be used in other parts of a project and are very interesting.

Note:
1. These "Building Blocks" have a number of different names for the same design and by changing a few components, they will operate in a completely different way.

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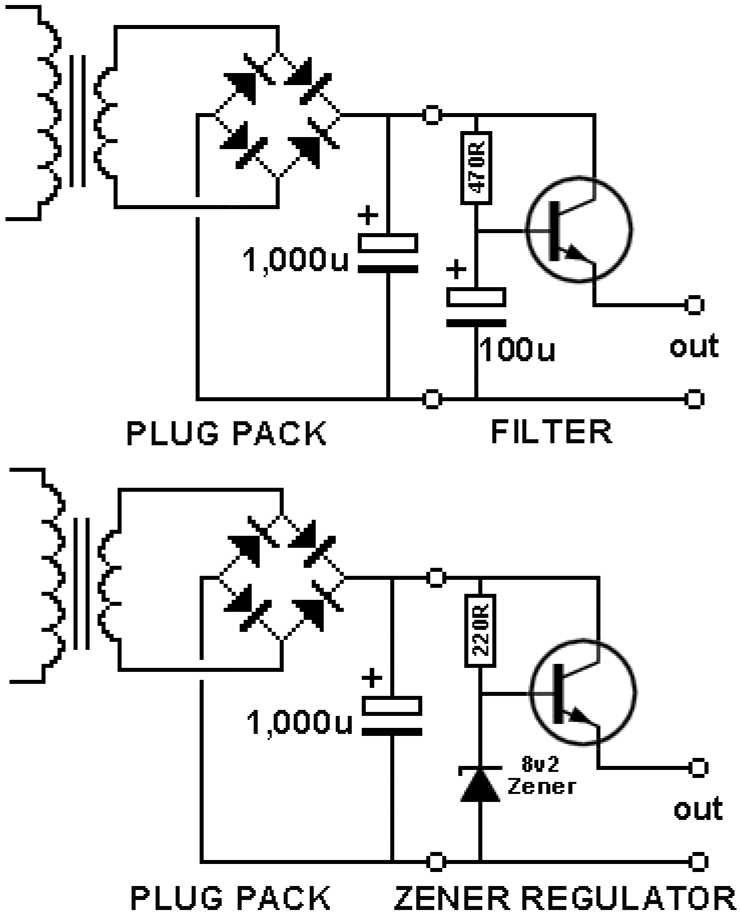

Fig 20. The PASS TRANSISTOR . . . also known as: THE ELECTRONIC FILTER

The transistor in the first circuit does not do anything. It merely passes the filtered DC to the output.
The second circuit delivers the voltage from 0v to a voltage just below the ripple, if the transformer supplies sufficient voltage and the 8v2 uses just the ripple-free part of the voltage.
We have already shown that 1,000u will allow the circuit to deliver up to 1 amp and the output voltage will have 10v ripple. This is is one of the limiting factors.
The other limiting factor is the transistor.
The output voltage will always be 8.2 - 0.7 = 7.5v
Suppose the voltage on the electrolytic is 20v, this means 20 - 8.2 = 11.8v will be across the 220R. The current through the 220R will be 50mA
The transistor has a gain of 50 so the output current will be up to 2.5 amps. But the circuit is only good for 1 amp and thus the limiting factor is the 1,000u.

The transistor, resistor and zener can be fitted to a plug-pack to regulate the output.
The output voltage will be reduced, but it will be much smoother.
The bridge and electrolytic are inside the Plug Pack and the 3 filtering components are connected to the leads of the Plug Pack. They can be considered a "Building Block." They reduce the ripple and provide a stable voltage that is lower than output of the Plug Pack by about 5v.
The circuit is a **PASS REGULATOR** as the current "passes" through the transistor. Another type of regulator is the SHUNT REGULATOR where the current is shunted (sent) to the 0v rail and you can "tap off" this "wasted current" and use it in a circuit. The Shunt Regulator is very wasteful.
The **Series Pass Regulator** is exactly the same as the **Common Collector Amplifier** or **Emitter Follower** stage covered in the first part of this course.
A signal on the base will appear on the emitter with 100 times more strength.
The **base is fixed** and so the **emitter is fixed** and it does not matter what happens to the collector voltage. It can rise to any value and fall to a value that is about 3v above the output voltage.
The circuit will not work if there is any ripple on the collector voltage. We can only use the "clean part" of the voltage.

Note how the transistor is drawn in the circuit. The emitter is drawn lower than the output of the Plug pack. This has been done to remind you that the output voltage will be lower than the plug-pack by a few volts. For 1Amp supply, the transistor will need to be rated at 2Amp or more so it is not overloaded.
BD139 transistors are rated at 1.5Amp but the gain is less than 100 @150mA and will be less than 20 at 1 amp.
TIP31A and TIP41A will handle 3A and 6A but the gain figures are under 100.
Obtaining a suitable transistor is very difficult and this circuit is really not practical.
The transistor we used in a prototype was BD679 (a Darlington transistor) rated at 6 amp and plenty of gain. It fits directly into the c, b, e, of the schematic but the symbol will need to be replaced with a Darlington symbol.

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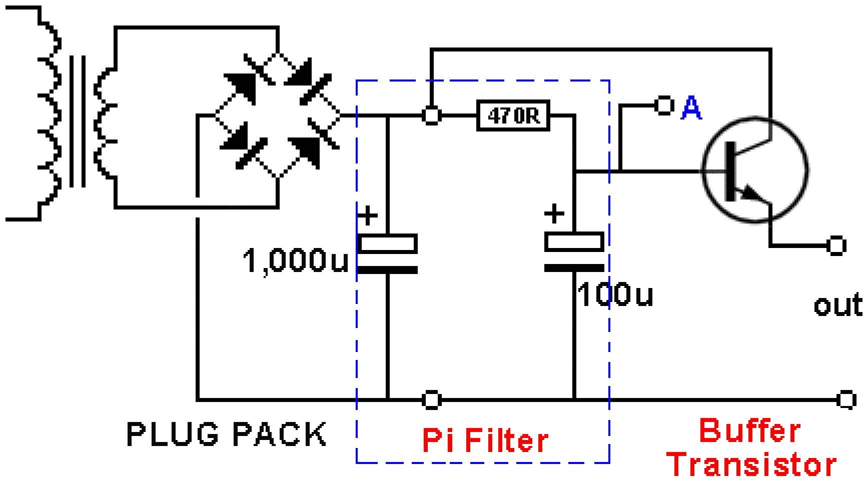
Some **Basic Electronics Courses** include theory on filters known as **"Pi Filters."** These are resistors, capacitors and inductors arranged to form the Greek letter "pi" - π).

(Remember: the circumference of a circle =$2\pi R$)
Although these arrangements do work, they are only 1% to 10% efficient as the **Electronic Filter** shown above in Fig 20.
Fig 20 is a pi-filter with a transistor buffer.
Here is the circuit re-arranged so you can see the "pi" section:



We explained the Pi section has a filtering capability of 100x for 10mA (the base current). When you compare this to 1,000mA it is only 1% of the required output current. If the 100u is increased to 1,000u, the output at **A** will be 10% of the capability of the Electronic Filter.
If the 100u is increase to 1,000u and the current is increased to 1,000mA, the voltage drop across the 470R will increase **100 times** and the pi filter as shown will be quite worthless.
If we replace the resistor with an inductor, the voltage-drop across the inductor will be less, but the size of the inductor will be ENORMOUS. The cost will be high and the ripple will be about the same as the RC filter.
Inductors have very little effect when the frequency is about 100Hz. But when the frequency is 40kHz, they have an improved effect of "400 times." That's why they are used in high frequency circuits.

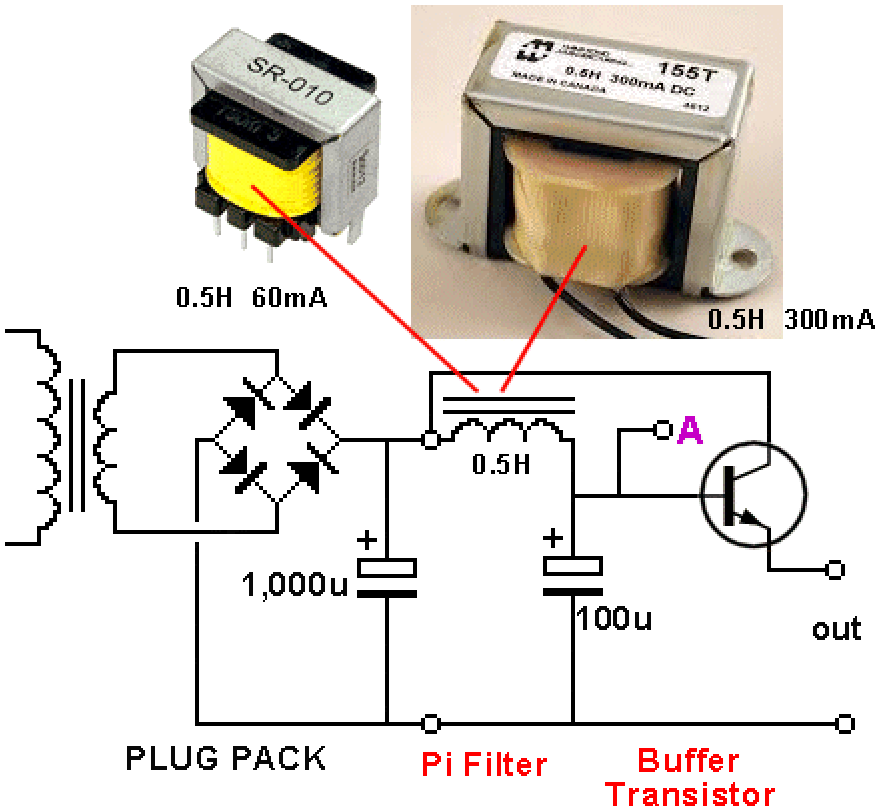


Fig 20a. The Pi Filter

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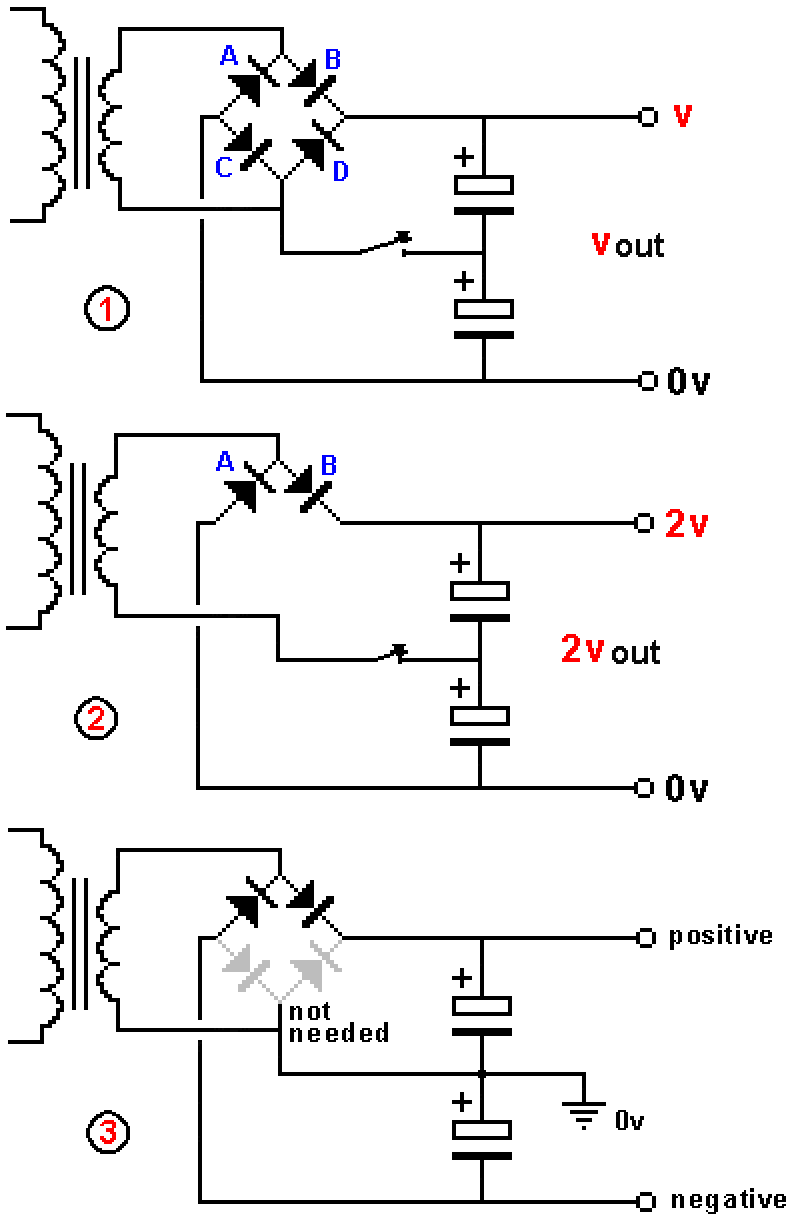

Here's a power supply circuit that creates three different outputs, depending on how you connect to the output and how the transformer is connected. By closing the switch in circuit 1, the output voltage doubles.
In the first circuit, the bridge is supplying two electrolytics connected in series. The output voltage is "V" and is about 1.4 times the voltage of the transformer.
When the switch is closed (in the first circuit) the output voltage is DOUBLED.
At the same time, an interesting thing happens. Two of the diodes are not needed.
The second circuit shows only diodes A and B are needed. The circuit is a full-wave voltage divider but the top electrolytic is charged via the positive half of the waveform and the lower electrolytic is charged via the negative half of the waveform. This means it is really a half-wave power supply.
The third circuit connects the join of the two electrolytics to "earth" to produce a positive and negative supply - with each being a half-wave supply. Since it is identical to circuit 2, the two lower diodes are not needed.

Fig 21. The Voltage Doubler and "+" & "-" Outputs

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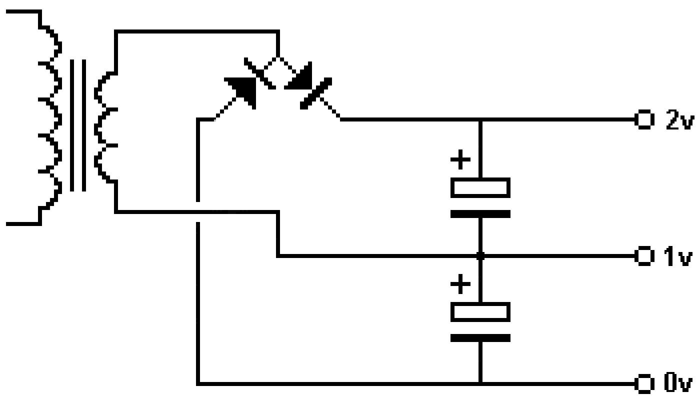
By re-arranging the outputs on circuit 3 above, we can get "v" output and "2v" output. Each output is a half-wave supply. The output voltage "v" is approx 1.4 times the AC voltage of the secondary winding.



By adding two diodes and two electrolytics, the circuit can produce "v" from a full-wave rectifier and a weak boost of 2v via a capacitor "charge-pump."

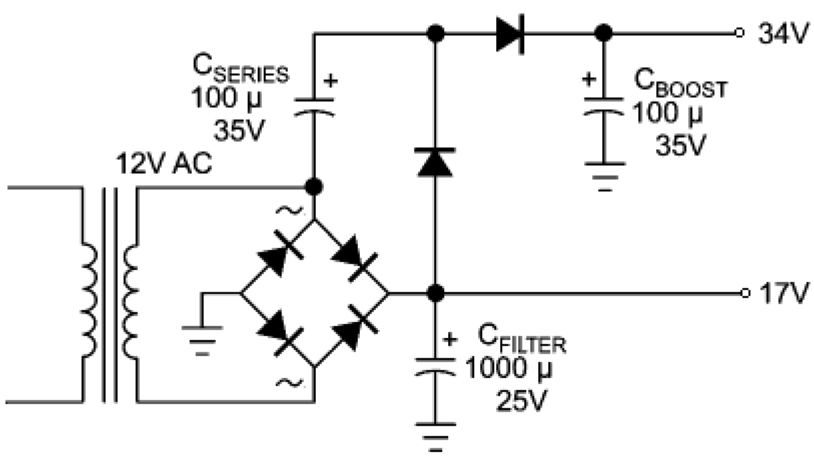


Fig 22. More Voltage Doubler Circuits

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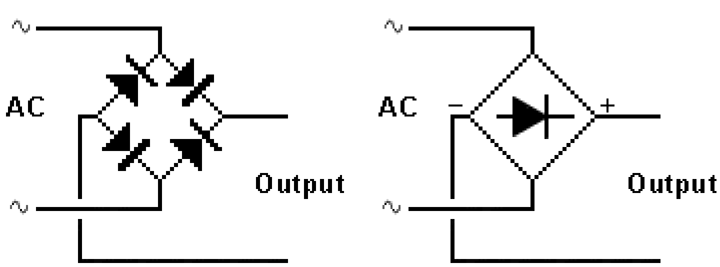
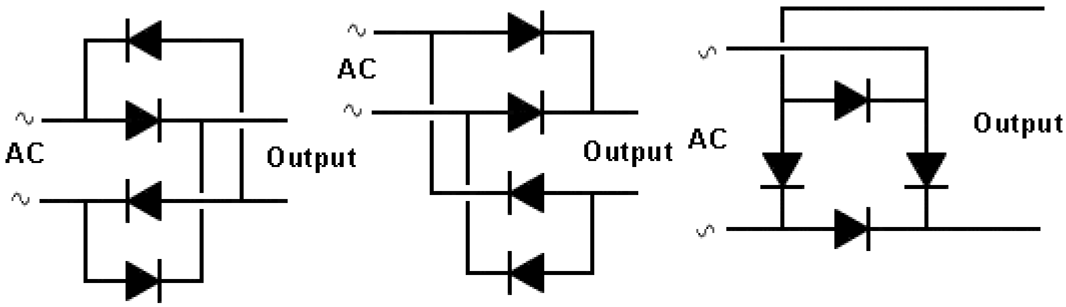
From the previous frames you can see a circuit can perform differently by merely changing one or two connections or adding one or two components.
That's why it is important to make sure the operation of the circuit is clear and is laid out in a way that can be easily recognised.

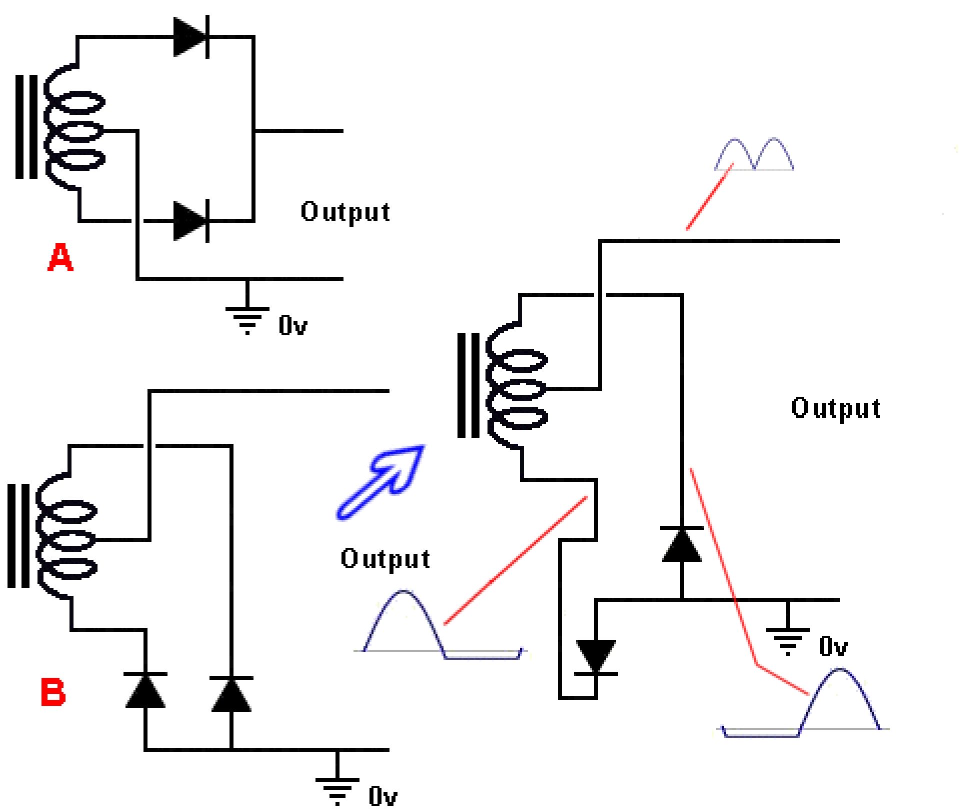


By drawing all the diodes in one direction, they can be replaced with a single diode in a diamond.

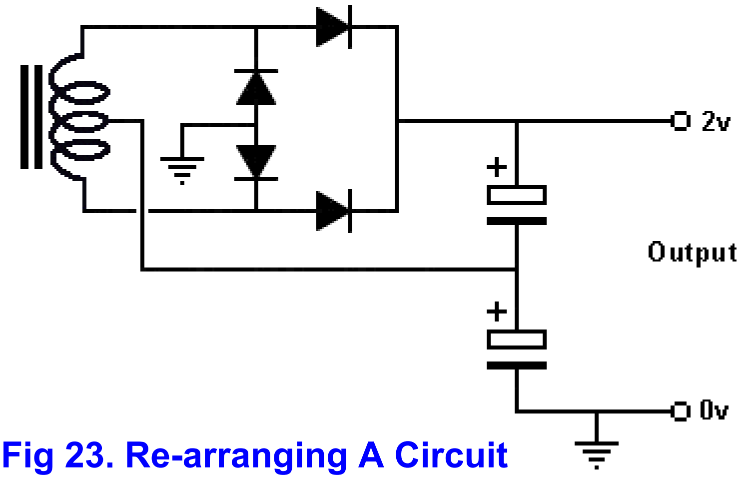
Here are three layouts that will take a few minutes to work out:



Normally a circuit is drawn so it is easy to see what is happening. But sometimes a re-arrangement can be helpful.
The normal way to show the output of a centre-tapped secondary is Fig **A**. But re-arranging it to Fig **B** shows the diodes can be heatsinked on the earth-plane (chassis).



The animation of circuit B show the first diode gets "flipped over" as soon as the bottom winding of the transformer becomes negative and this puts the diode in "forward bias" where it starts to conduct and a maximum of 0.6v develops across it. This prevents the bottom winding moving any further and the centre-tap and top output increase in voltage. Note the voltage of the top winding is double the voltage on the centre-tap. But the voltage on the top winding simply goes to the other diode and nothing happens (the diode is put into "reverse-bias bias" mode and the voltage "sits" on the cathode and does nothing). This gives the centre tap an output to deliver current to the next section of the circuit (possibly a filter section).
Exactly the same thing happens with the other portion of the waveform.
There is a lot to understand in this animation. The output "pushes" against one of the diodes that is forward biased and thus it will drop 0.6v and create a "rigid point" for the waveform to push out the other winding and into a filter section. At the same time the other winding is supplying twice the voltage to the unused diode and nothing further is happening as the diode is reverse biased.



It will take a minute to work out if the circuit on the left is a voltage doubler or a full-wave supply:

(It's a voltage-doubler via two half-wave supplies. Two of the diodes are not needed, as explained above.)

Fig 23. Re-arranging A Circuit

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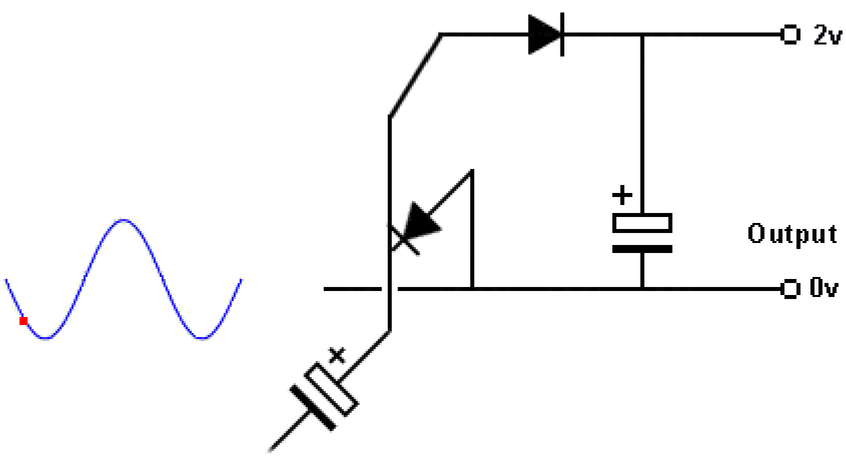

Fig 24. Voltage Doubler Animation

The animation shows a capacitor being charged via an input waveform and then being "jacked-up" by the waveform to deliver its voltage to a storage section made up of an electrolytic. The result is a voltage that is about twice the amplitude of the incoming waveform.

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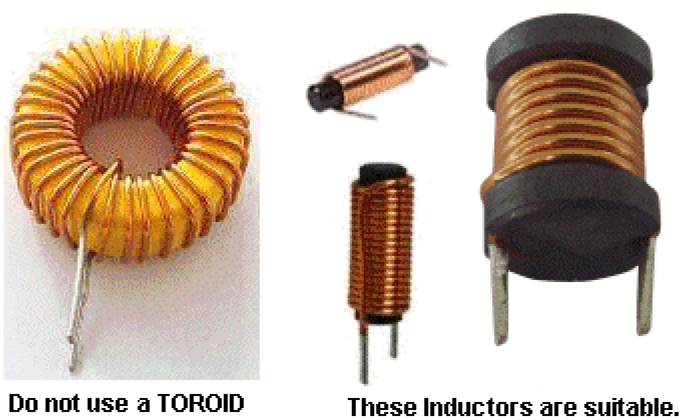
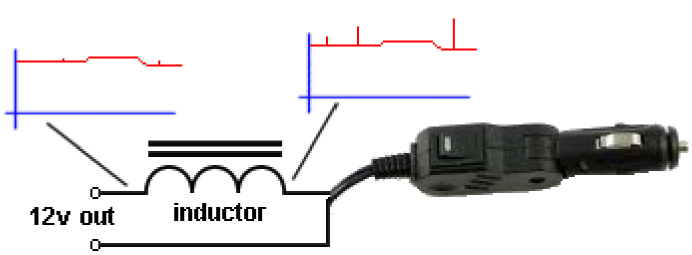
There is one more topic in this section.
It's **SPIKE SUPPRESSION**.
Suppose you are connecting to a battery in a vehicle and the supply has a lot of noise from the ignition and generator (alternator).
This noise can be as high as 40v and the requirement is to suppress this noise while allowing a current of up to 5 amps to flow.
The filtering covered above removed a 5v ripple by dropping it across a filter network but we now have a 12v (up to 15v) supply and require ALL the voltage to pass to our equipment.
In other words we need a filter-network with ZERO voltage-drop.
This is only possible with an INDUCTOR.
An INDUCTOR is a coil of wire on a core made of iron or ferrite. These are the same material and they are able to absorb a lot of magnetic flux 3,000 to 10,000 times more flux than air.
The first thing you do when choosing an inductor is select a wire that will allow the 3 amp current to flow. You need thick wire for 3 amp as thinner wire has more resistance (per turn) and it will heat-up to create a very warm inductor.
Next you have to wind say 30 turns on a ferrite core and try it.
There are no examples in any catalogue of how an inductor will perform in a circuit with spikes.
There are lots of formulae but these are worthless as no-one has used a formulae and applied it to any of their inductors.

The inductor we are using will not get rid of ripple or fluctuations in the supply. It will only remove "spikes." A spike is a very fast, brief, pulse and it has a high amplitude.
As this high amplitude wave enters the first turn of the inductor, it allows a high current to flow and this produces a high magnetic flux. The magnetic flux cuts the other turns of the coil and this produces a voltage in each of the turns that is in the opposite direction to the incoming voltage.
When the spike enters the second turn of the coil it sees a back voltage that cancels some of the incoming voltage. Thus the current it can produce is less and the flux it produces is smaller. This continues for each turn of the coil and by the time the spike reaches the end of the inductor it is zero. (This is a description to make it easy to understand how the inductor works. It is not entirely in accord with the actual production of the magnetic flux).
No other components are needed as the inductor suppresses the spike.
Provided the inductor has sufficient number of turns, the spike will be suppressed. A small voltage-drop (mV) will develop across the inductor due to the 3 amp current-flow.
Each turn on an inductor can suppress between 1v to 10v so you have to wind a number of turns on a core and try it.
Adding an inductor is a form of DECOUPLING. You are separating the battery from your supply and preventing spikes up to 40v entering your equipment. The rails are already very "tight" as you can draw over 100amps via a cigarette lighter socket and that's why a 20 amp fuse is provided in the vehicle.
Other terms for the inductor include: LINE CONDITIONING, LINE FILTERING, SPIKE SUPPRESSION - but not Surge Suppression or Voltage Regulation. The output voltage of a cigarette-lighter socket will go as high as 15v - 16v, depending on the condition of the battery and the charging via the alternator.



Do not use a **TOROID**. The DC current through the winding will create magnetic flux that will saturate the core and the spike may not be absorbed.



The inductor will reduce the spikes but not the ripple or fluctuations in the 12v.

Fig 25. Spike Suppression Inductor

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A 1-amp **Linear Power Supply** is a reasonably difficult power supply to build.
1 amp diodes (such as 1N4004) are really only suited to 750mA as the voltage across them increases as the current increases and at 1 amp, the voltage-drop is 1.1v. This gives a wattage dissipation of over 550mW as each diode is conducting for half the time in a full-wave supply.
The diodes will get very hot and need heatsinking.
The ripple from a 1-amp supply with 1,000u will be 5v p-p and 2,200u is needed for 2v p-p ripple.
The output needs further filtering and regulation to make it suitable for most electronic circuits and all this can be done with a low-cost **Switch-Mode Power Supply** or A **3-TERMINAL REGULATOR** as shown in figures 11 to 14 above.
When the input voltage is **much higher** than required by the regulator, the 5v p-p ripple will be way-above the voltage needed by the regulator and will not processed by it.
That's why you need a high input voltage if you are drawing the full rated current of the supply.
This high voltage will produce a lot of heat in the regulator and it will need a very large heat-fin.

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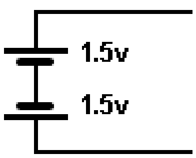
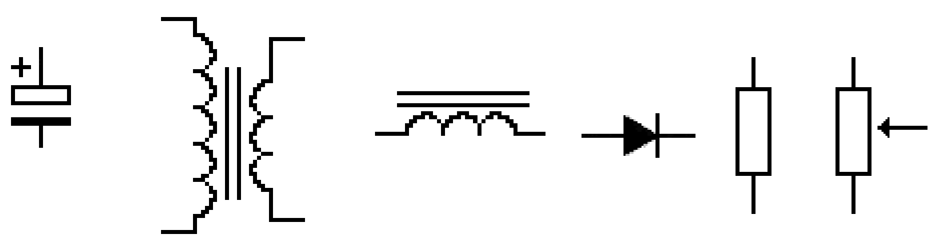
POWER SUPPLY TEST - 2

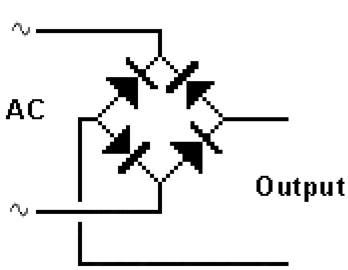
1. What is the output of this circuit:



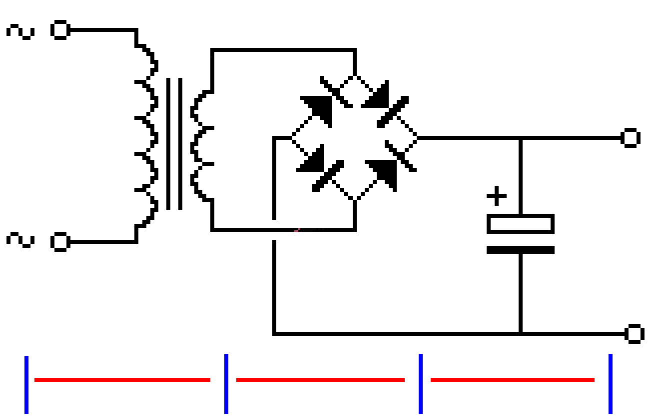
2. What is the output voltage of four 1.2v rechargeable cells in SERIES:
3. Can cells be connected in PARALLEL?
4. How many cells in a 9v battery?
5. Is it dangerous to touch the NEUTRAL lead of the MAINS?
6. What is the name given to the term: "cycles per second"?
7. Name two types of capacitor
8. Name the component contained in a "bridge."
9. What is another name for a LINEAR REGULATOR
10. Name these: "v" "mA" "R" "k"
11. What is the approx voltage-drop across a power diode?
12. Is current measured "across a battery" or via a "cut in the circuit."
13. Most plug-packs employ: Half-Wave Rectification or Full-Wave Rectification.
14. Name these symbols:



15. Will this bridge produce an output?



16. Name the 3 sections:



17. What is the approx value of capacitance for the electrolytic in a 1amp power supply.
18. What is the name given to improving the ripple from a Plug Pack.

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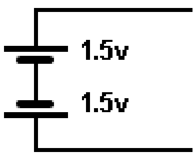
POWER SUPPLY TEST - 2 Answers

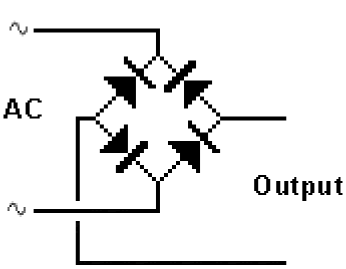
1. The output of this circuit is ZERO because one cell is around the wrong way and the voltages cancel.



2. The output voltage of four 1.2v rechargeable cells in SERIES is 1.2v x 4 = 4.8v or 1.5v x 4 = 6v or 3.6v x 4 = 14.4v
3. Can cells be connected in PARALLEL? Yes
4. How many cells in a 9v battery? Six
5. Is it dangerous to touch the NEUTRAL lead of the MAINS? No. But the wires may be connected incorrectly and the neutral may be the ACTIVE. Never take a risk.
6. What is the name given to the term: "cycles per second"? Hertz Hz.
7. Name two types of capacitor: Ceramic and Electrolytic
8. Name the component contained in a "bridge." Four DIODES
9. What is another name for a LINEAR REGULATOR - 3-Terminal Regulator, Regulator,
10. Name these: "v" "mA" "R" "k" Volts, milliamps, Ohms (resistance), kilo ohms
11. What is the approx voltage-drop across a power diode? 0.6v to 1.1v
12. Current is measured via a "cut in the circuit."
13. Most plug-packs employ Full-Wave Rectification.
14. Name these symbols:

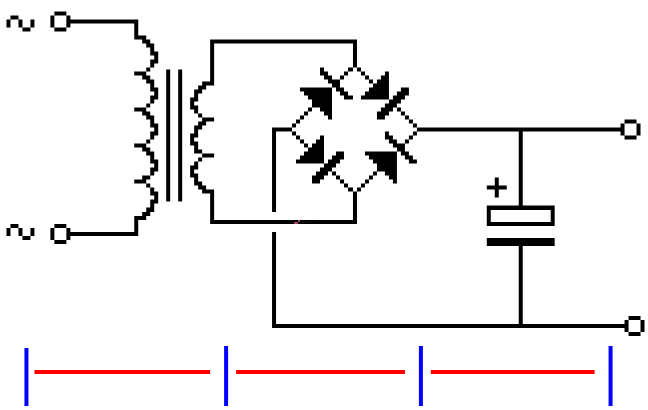
electrolytic transformer inductor, choke, coil diode resistor potentiometer

15. Will this bridge produce an output?



One of the diodes is around the wrong way (top, right diode)

16. Name the 3 sections:



CONVERSION RECTIFICATION SMOOTHING

17. What is the approx value of capacitance for the electrolytic in a 1amp power supply: 1,000u

18. What is the name given to improving the ripple from a Plug Pack.
Filtering, buffering, regulating, smoothing, using a PASS Transistor, electronic filtering, Ripple Suppression,

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HOW TO USE A POWER SUPPLY

You must be very careful when designing and testing a circuit on a **POWER SUPPLY**.
When we talk about a **POWER SUPPLY** we mean a **BENCH SUPPLY** or **BENCH POWER SUPPLY** or **REGULATED POWER SUPPLY** or **CURRENT LIMITED SUPPLY** or **TEST SUPPLY**.
These are all names for a Power Supply fitted to a test bench and may be as simple as a Plug Pack, Battery Charger, Regulated Supply, Dual Supply, Dual Tracking Supply or Digital Supply.
Here are some photos of the type of equipment you may use:

Power Supply with "Meters"

Plug Pack Regulator
built by a reader

A Power Supply project by:
http://www.ecrostech.com/General/MiniPsu/Bench.htm

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When using a **Bench Supply** (any of the above), it is important to remember that it MUST be **EXACTLY THE SAME** as the supply you will using for the project, if you want to get accurate results.
If you are using AA cells in the project or rechargeable cells, 3.6v Li-ion cells, button cells, coin cells, 12v rechargeable battery or solar cells, the Bench Supply will produce different results.
This is because the IMPEDANCE of each supply is different.
In other words, the ability of each supply to deliver peaks of current will be different.
The circuit may work completely differently on Solar Cells and you are wasting your time designing it on a Power Supply.
If the project will use a 12v rechargeable battery, designing it with a battery on long leads with meters included, will produce completely different results. Even the on/off switch can make a difference.

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That's why it is recommended to use exactly the same supply as will be used in the final design of the project.
This all comes down to the need for an expensive Bench Supply.
No project will incorporate an expensive supply, and thus a "showy" Bench Supply may look impressive, but "function-wise" a set of AA cells is all that's required.

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When designing a project on a Test Bench, the leads to the power supply and meters, may introduce additional resistance and if the circuit is operating at high frequency or requires pulses of high current, this resistance can change the operation of the circuit to a point where it will fail to work. This happened with a Flashing Beacon Multivibrator circuit driving 18 watt lamps. The additional resistance of the leads prevented the circuit flashing. The reason is this: Lamps take 6 times more current to turn ON and this current produced a voltage-drop that prevented the circuit flashing.
The secret to the operation of many circuits is "tight power rails" and this requires short leads and electrolytics or capacitors in a number of critical places.
Using a set of cells on short leads or a rechargeable battery on short leads allows you to see the exact impedances you are dealing with, whereas a power supply with internal meters and current limiting will have an unknown "hidden" impedance.

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ONE LAST HINT

The best way to design a project is with a set of AA cells and also a set of "used" cells.
This will give you an idea of how the project will work during the life of the battery.
Cells are only "fresh" for a short period of time and most of the use is carried out at a reduced voltage.
You need to know how the project will work during this time and find out if any faults develop.
A set of AA cells will not be capable of delivering a high current and if a "short" develops during designing, nothing will be destroyed.
All this is a reflection of over 40 years designing electronic projects and overseeing new developers starting with an impressive "current limiting" Power Supply and wondering why the project (an amplifier) did not work successfully on batteries.
The supply was a constant 12v, whereas a set of cells soon drops to 10v and the performance of an amplifier falls considerably.

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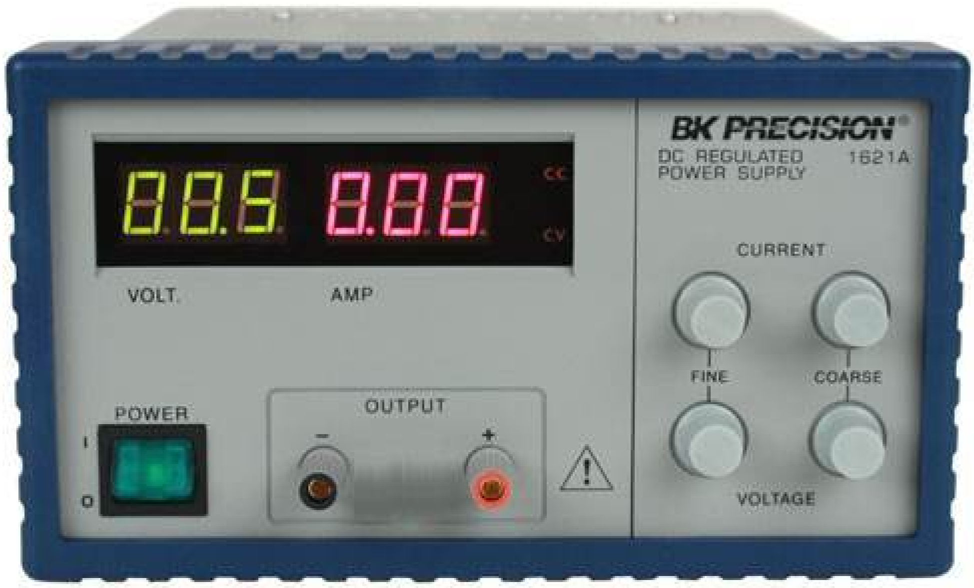
What does CONSTANT VOLTAGE mean?

We normally don't talk about **Constant Voltage** from a Power Supply because we assume the power supply will be suitable for the requirement and deliver the "dialed" voltage over the range of current we are requiring.
If the power supply is good-quality, a 1 amp supply will deliver up to 1 amp at say 12v with ripple as low as 5mV and the voltage will not drop below 11.95v.
Obviously a Plug Pack is not **Constant Voltage** as we have said the voltage will drop 3v - 7v and the ripple will be as high as 5v peak-peak.



In the photo above, the B&K **Power Supply** can be adjusted from 0v to 30v and 0 Amp to 3 Amp.
Your project is connected via a red lead and black lead and banana plugs that push into the sockets on the front.
You then "dial up" say 12v using the coarse "voltage" control and then dial up the current via the coarse "current" control.
If your project requires 100mA, and you dial up 200mA, the project will work perfectly and the voltage will remain constant.
None of the special features of the power supply are being used.
In other words the Power Supply is "stronger" than what you need.
The voltage will remain at 12v and this is called **CONSTANT VOLTAGE.**

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What does CONSTANT CURRENT mean?

Constant Current really means **MAXIMUM CURRENT**.
If we take the same B&K power supply (shown above) and turn the current down to 100mA, the voltage will remain constant @12v but if the project is say an amplifier and you turn up the volume, it will want to take a higher current. The power supply will prevent your project taking more than 100mA and it does this by reducing the voltage.
In other words, the Power Supply is "weaker" than what you need and it cannot supply the required current.
This is exactly what happens with a "used" battery. It will show 12v when tested with a voltmeter on NO-LOAD (amplifier not connected), but when the amplifier is turned up, the voltage from the battery will drop.
This is a simple explanation of the characteristic of a Power Supply called: **constant voltage/constant current automatic crossover**. The continuous transition from constant current to constant voltage in response to load change.
In other words the **VOLTAGE** is the "quantity" that is **maintained** until the "dialed-up" current is reached. Then the voltage **drops** so the **MAXIMUM CURRENT** (100mA in this case) is **not exceeded**.

Note: A **Power Supply** does not deliver a CONSTANT CURRENT to a Project.
The project determines the current and if it requires a LOWER CURRENT, the supply delivers the lower current. So, obviously, a Power Supply is not delivering a Constant Current and it never delivers a constant current unless the load is a fixed wattage such as a resistor. In all other cases it delivers **UP TO** the maximum current.
A **Power Supply** delivers a **MAXIMUM CURRENT** when in the **CONSTANT CURRENT** mode.
When the project requires a higher current, the voltage to the project is reduced.

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MEASURING VOLTAGE & CURRENT

When using a Power Supply, you need to 'SET" the voltage. This means you need to adjust the

voltage to suit the project.
Sometimes this voltage is very critical.
Microcontrollers and TTL chips require a voltage between 4.5v and 5.5v for correct operation.
Other circuits and devices and chips can operate on supplies from 2v to 15v or up to 48v (such as phone-line voltage) and you will need to work out the most suitable voltage BEFORE connecting the project to a Power Supply.
You cannot always work out the supply voltage by looking at a project or a circuit diagram.
Sometimes a special chip may determine the low voltage (such as a microcontroller or TTL chip) and sometimes a motor or relay will determine the voltage.
If a project is designed for 12v, you should not increase the voltage by more than 2v as some sections of a circuit (especially the output stages) will take a lot more current when the voltage is increased.
Once you have determined the voltage, you can set up your project and connect it to a power supply as shown in the following diagram:

"Dial-up" 12.5v and 300mA for the project. The on-board 5v regulator will convert the 12.5v to 5v. The circuit requires a maximum of 200mA, so the 300mA capability of the Power Supply will allow the circuit to work perfectly and if a short-circuit occurs, the maximum current from the Power Supply will be 300mA.
The B&K Power Supply shown in the photo (and all Power Supplies with Constant Current feature) does not show the current taken by the project (unless the project is taking the full 300mA.) You have no idea of the current taken by the project and if the project taken more than 300mA, the voltage will drop but this may not show on the display as the display shows the "dialed" voltage.

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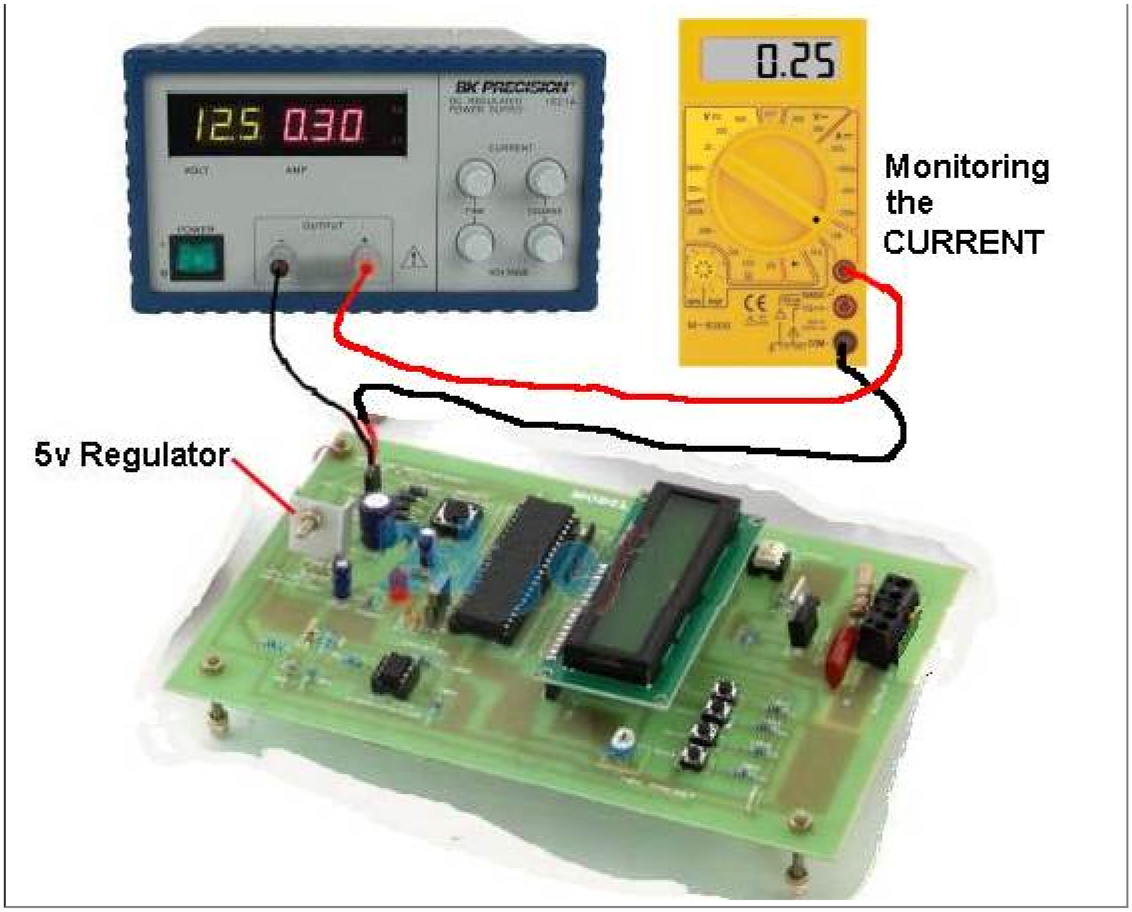
To observe the current taken by a project, you will need to include an ammeter as shown in the photo:



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THE FUSE

A fuse is simply a thin piece of wire.
But it can be designed to act quickly or slowly.
A "quick fuse" is called **FAST ACTING** and a "slow fuse" is called a **DELAY FUSE**.
A **FAST ACTING** fuse is also called a **NORMAL FUSE**.
It takes a lot of skill and knowledge to fit the correct fuse and also replace a fuse with the correct type.
A fuse doesn't really protect anything.
If a circuit gets overloaded, the fuse generally remains intact until one or more of the components "blows up" and the higher current heats the wire in the fuse and it melts.
The most common fuse in electronic work is 1 amp, 2 amp and 3 amp.
The rating "1 amp" is called the RATED CURRENT and is the current the fuse will handle for many years.
The term "FUSING CURRENT" is the value of current that will cause the fuse to melt. The time will depend on the construction of the fuse.
A normal fuse will allow about twice the rated current to flow and during this time the fuse can actually start to glow. This will oxidise the tin coating and the wire will gradually start to deteriorate. This will allow the fuse to fail at any time.
A DELAY FUSE is made with a piece of wire from one end and another from the other end and the two are soldered in the middle with a dot of solder.
If the two wires start to get hot, the solder melts and the wires separate.
This can happen at currents as low as 1.5 amp.
With fuses below 500mA, the wire is very thin and the current can gradually damage the coating and eventually it will fall apart for no reason.
As you can see, the fuse does not fail until at least 50% overload occurs and most transformers are not designed for this amount of overload.
Thus the transformer will fail and that's why some products have a 500mA fuse on the primary.
By the time the fuse fails, the transformer is "cooked."
The alternative to a fuse is a POLY SWITCH. This is covered in the next section.
Alternatively, a low value resistor can be used.
Sometimes a resistor is a good solution because, as the current increases to say twice the operating current, the power (heat) dissipated by the resistor will increase 4 TIMES.

This will damage any normal resistor.

PICO FUSES

PICO Industries developed a number of very small fuses with ratings from 100mA to 5 amp in a thin glass tube and having wires out each end so the fuse can be soldered to the PC board.
These small fuse became to be know as PICO FUSES and they are simply a "wire-in" fuse, contained in a very small glass tube.
Sometimes they are dipped and sealed.
Some of these fuses are hard to identify and difficult to determine the current rating.
You will need a multimeter to detect if the wire is intact. If is damaged, you will need to pull it apart and use a digital caliper to measure the diameter of the wire.
You will then need some new ones to pull apart and measure the diameter of the wire.
If there is a little spring inside the glass tube or a dob of solder, the fuse is a "SLOW-BLO" (DELAY) and it must be replaced with the same type.
A 1-amp "slow-blo" fuse will accept up to 3 amp for short periods of time and not get weakened because the wire is thicker than a normal 1 amp fuse. It works on the principle of the wire getting hot when 1.5 amps flows and the low-temperature solder melting.
When a power supply is turned ON, the electrolytics are uncharged and a very high current flow initially to charge them.
Both types of fuses will heat up during this time and you will be able to see the wire "sag" and then tighten again.
This process will gradually damage a normal fuse, whereas a delay fuse will not be affected.
There are hundreds of different types and styles of fuses for automotive, household, appliance and industrial protection.
If a fuse keeps blowing for no apparent reason, the first thing to do is refit the fuse up to 5 times and then use a delay fuse.
You cannot go to the next value as it will be 30% to 50% higher rating and the fuse you are already using is allowing up to 50% higher current to flow, before it fails.
If you fit a "stronger" fuse, the power supply may not be able to deliver sufficient current to activate the fuse and the equipment will "sit and burn" if a short-circuit develops.
Fuses in amplifiers are the hardest to replace because the amplifier takes a varying amount of current, according to the loudness of the music.
These fuses are generally "slow-blo" (delay) and the output wattage can be up to 10 times more than the average current when "loud thumping" is produced.
That's why you need to go by the manufacturers recommendation, as they have tested to equipment and come up with a value that does not prematurely fail.
This just a discussion to make you aware of the two different types of fuse and the approx current they are capable of handling.

AC FUSES

The current rating marked on the side of a fuse is **DC CURRENT** in **AMPS**.
There is no such thing as an "AC Fuse."
All fuses can be used in AC circuits.
In an AC circuit, the current will be say 1 amp for part of the cycle and less than 1-amp for the remainder of the cycle.
The heating effect on the wire inside the fuse will be exactly the same as a DC current of 1 amp.
This applies to all household fuses. A 10 amp fuse will allow 10 amps to flow and not be damaged or deteriorate. But what really happens is 14 amps will flow during the peak of the wave and less than 10 amps for the remainder of the cycle. The 14 amps is not present for long enough to overload the fuse.
Household fuses consisting of a length of wire are called "normal fuses."
A circuit breaker is called a FAST ACTING device and can be as fast a ONE CYCLE.
It detects excess current by producing magnetic flux from two turns of wire made from the conductor carrying the current. This magnetic flux is detected by a Hall device and a relay is activated to open the circuit. This is a totally different principle to a "hot wire" fuse.

DIFFERENT TYPES OF FUSES


surface-mount
low-ohm resistors
delay fuse
wired fuses
blade fuse
blade fuse
cartridge fuse
blade fuse
poly fuse
blade fuse
high-current fuse
high-current fuse


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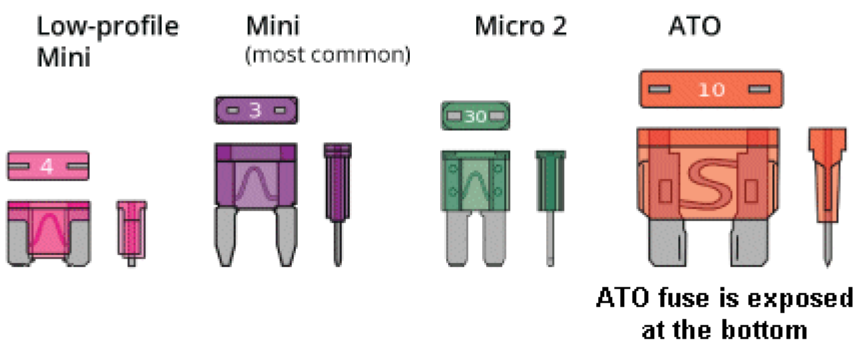
www.electricaltechnology.org
Different Types of Fuses

**These images show 5 in-line fuse holders,
then panel-mount fuse holders and fuse clips at the bottom**



These images show blade fuses

Low-ohm surface-mount resistors can be used as a fuse because the current flowing through the resistor will create heat. The amount of heat is a product (multiplication) of the current flowing and the value of resistance. Basically you can say the wattage dissipated is four times greater when the current doubles. That's why it heats up and fails.
But there is a voltage drop across the resistor AT ALL TIMES and you must take this voltage drop into account when designing the project.
There is no voltage drop across a "normal" (wire) fuse.

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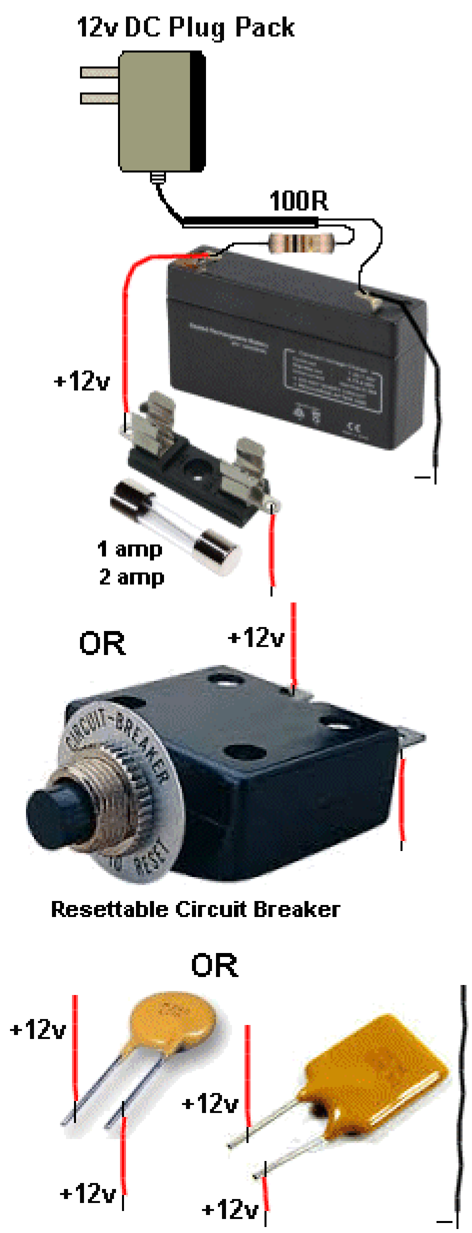
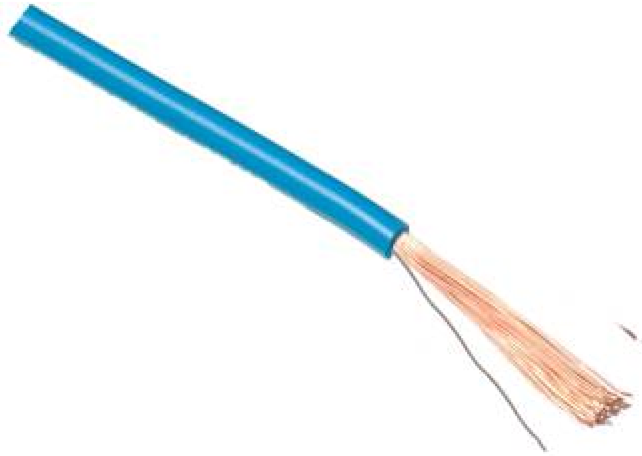
POLY SWITCH

Designing and testing circuits up to 1 amp has very few problems.
Most parts carrying 1 amp do not get very hot and the wiring can be light duty cable.
When the current is greater than 2 amp, you need to take additional precautions because the power supply you are using will deliver a high current and there is a high current flowing most of the time.
If you are using a power supply with current-limiting, use this feature, but if you are using a 12v battery, up to 100 amp can flow if a short-circuit is created. This will burn the leads and even the tracks on a PC board.
I am very careful whenever I use a 12v battery because two wires touching will burn out all the wiring.
There is a simple way to protect everything. It is called a FUSE.
It is the cheapest and best item.
You can use a 1amp, 2 amp or 3.15amp fuses
You can also use a circuit breaker.
You can find a 10 amp circuit breaker in a damaged power board. Just pull the power board apart and re-use the circuit breaker.
Finally you can use a POLY SWITCH.
This is a crystalline structure that has a very low resistance (something like 0.05 ohms). When a current flows through the structure it gets slightly warm. When a higher current flows, it gets slightly warmer and its resistance increases.
This causes more heat to be produced (by the structure) and it gets hotter and hotter. Within a very short period of time its resistance is very high and only a very small current flows.

This current is called "Leakage Current" and can be from 20mA to 100mA.
The voltage of the supply and the leakage current will create heat in the device to keep it in a state of high resistance.
A Poly Switch can take from 10mS to 10 seconds to activate (respond) and this depends on the voltage of the supply and the short-circuit current (the voltage of the supply has an effect on the maximum current flowing).
You need to remove the supply and wait a few seconds for the Poly Switch to cool down.
But there is one more thing to remember about a Poly Switch. It also has a VOLTAGE RATING.
When the Poly Switch "goes open" the voltage of the supply will effectively be across the device and if it is rated for 30v and the supply is 100v, the device will breakdown due to the overvoltage and it will either leak more current or breakdown completely and deliver a lot more current to the "short."
Understanding how this device works needs a lot more understanding than first meets the eye and is actually a "final year" component consideration as you would need to buy a number of different types and work out which is the most suitable.
In most cases the current-rating of the device (say 1 amp) is the normal current for the device and it will go open when twice this current (2 amps) flows. You have to decide if the "trip current" will protect the product you are designing.
All the protection devices mentioned above will prevent the leads burning out but nothing will protect any of the electronic components from being damaged.

Here are 3 ways to protect your project from going "up in smoke!"





You can make your own fuse by taking one strand of wire from multi-strand hook-up flex and use it to touch the positive terminal of the battery. If it "goes up in smoke," the circuit is taking too much current.

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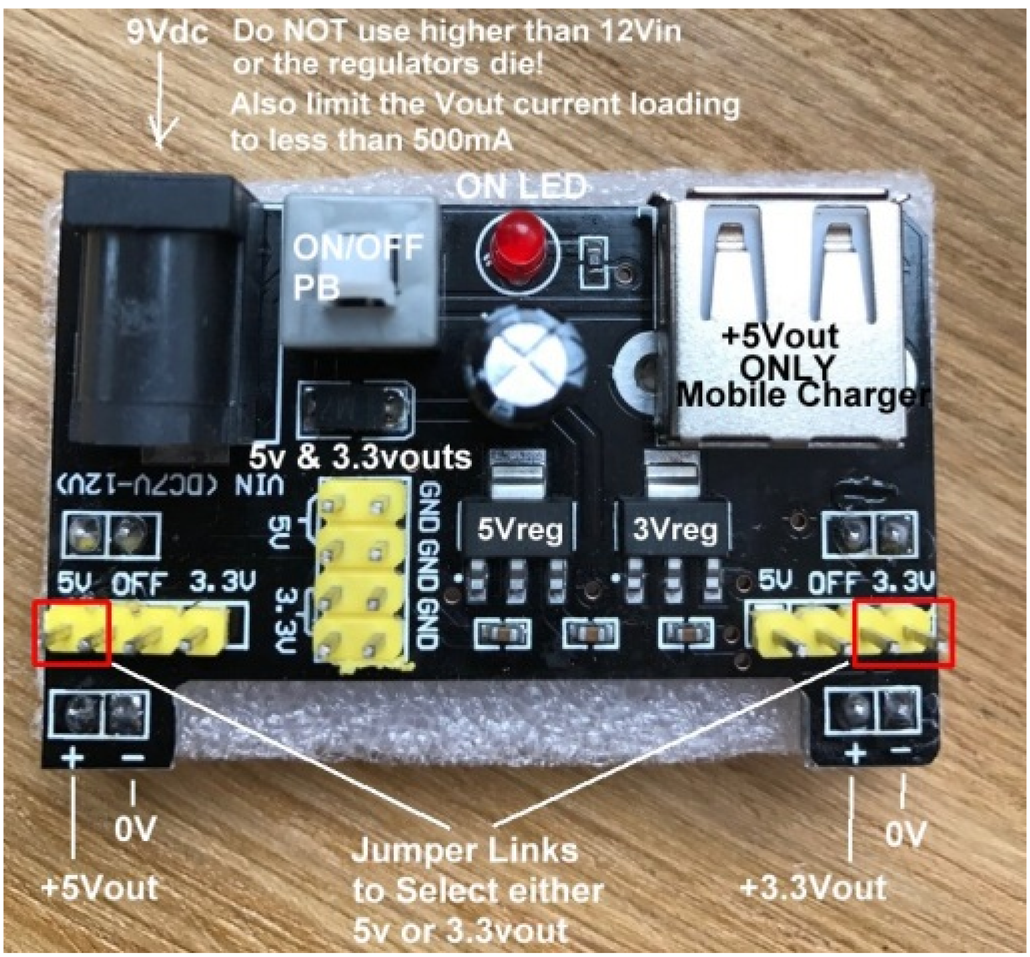
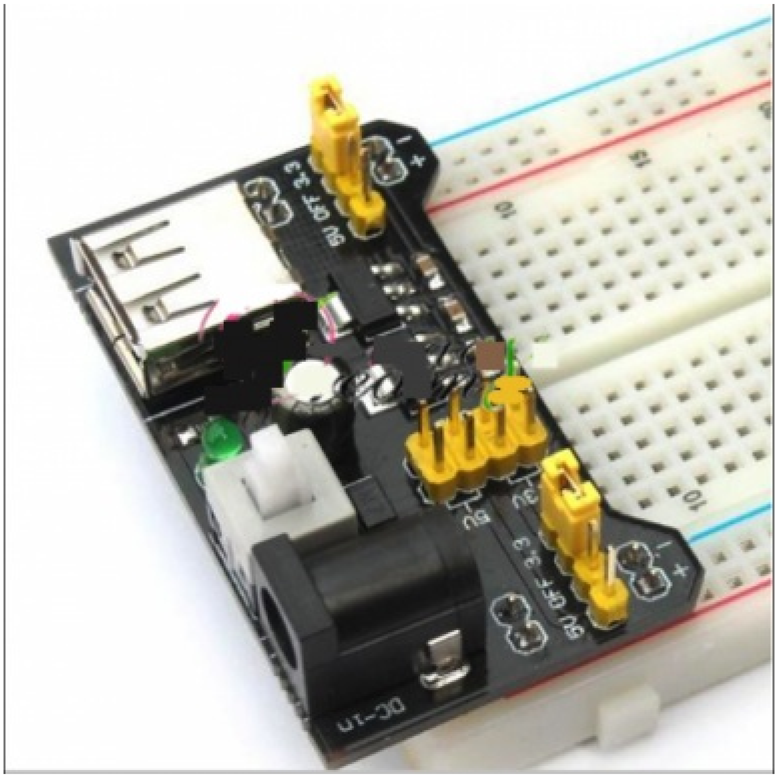
EXPERIMENTING

When building and designing circuits, you will find a BREADBOARD is a very good platform for building the circuit. It consists of many holes that are joined under the board with springy metal strips that grip the end of the leads and join them to the other components.
You will learn where the strips are placed under the board from diagrams on the web and the long strips that run from one end of the board to the other are called BUSES.
Sometimes these are cut in the centre and you have to join them with JUMPERS.
These buses allow the POWER RAILS to be available for the whole length of the board and they are sometimes marked with a red line and black line.
You can also get a POWER MODULE that clips onto the end of the board and it will deliver 5v and/or 3v3 to the POWER RAILS.
The following two images show the POWER MODULE and one fitted to a breadboard.





You need to select the voltage for each rail with a tiny jumper (supplied with the module). You can have 5v at the top and 3v3 at the bottom.
The 5v USB connector is for powering an external device. Do not attempt to use it to power the module. Each voltage will supply up to 500mA.
Before you connect a power supply to your circuit, it is very wise to use a supply made from AA cells. This will deliver a very smooth voltage and if the cells are not new, the current will be limited and the components will not get destroyed, if a fault is present. It will also prove your circuit will work on a slightly lower voltage.

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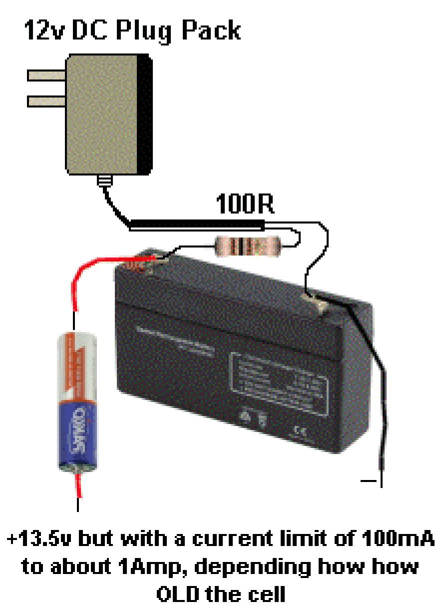
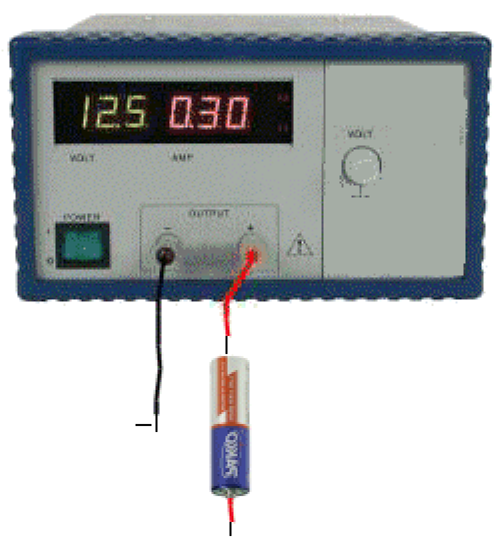
HANDY HINT #1:





Here's a cheap way to protect your project from damage when testing it for the first time.
If you don't have any low value resistors of 1 watt to 3 watt rating, you can use a very old AA (dry cell) in series with the positive lead.
It will add a small voltage to the output, but it will also LIMIT THE CURRENT and prevent your

project being damaged.
The actual current will depend on the age of the cell and a **very old** cell will be ideal as it will limit the current to as little as 100mA.
It may get charged in the reverse direction during its use and it may get warm or **hot**, depending on the fault in your project, but you can throw it away after use, rather than throwing away your project.

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PROBLEM 1:

If your project contains a globe (such as on the output) you cannot use a Power Supply with **CURRENT MONITORING**.
A globe takes up to 6 times more current to start to turn ON (because the filament is cold and has a LOW resistance) and the Power Supply will see this as a LOAD and reduce the voltage. The voltage may be so **LOW** that the rest of the circuit does not work and this will create a problem. You will think the circuit is FAULTY. Some Power Supplies have a LED to indicate it has gone into **CURRENT-LIMIT MODE**. In the example above, the globe is 36watt and takes 3 amp when illuminated. But it takes over 10 amp to start to illuminate and the supply has only a 5 amp rating.
The Multimeter is indicating 3.25 amp but the globe is not illuminating. The Supply has "shut down" to less than 4v because the **CURRENT LIMITING** circuit has reduced the output current to 3 amp and the only way to deliver 3 amp is to reduce the voltage to about 4v.
The **CURRENT MONITOR (current limiting circuit)** cannot be turned off and this supply is not suitable.

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You need a **HIGH CURRENT SUPPLY** to test a car globe.

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PROBLEM 2:

A power supply is set to 12v. It is a 0-30v power supply with a maximum current of 5amps as shown on the front of the supply.
When the load is connected, the output voltage drops to 7.6v Why?

The load is OVERLOADING the power supply.
It is protecting itself.
It can only deliver a maximum of 5 amps.
As the voltage produced by the power supply increases from 0v, the current through the load also increases and when the voltage reaches 7.6v, the maximum of 5 amps flows through the load.
At this point the voltage does not rise any further.
The load connected to the power supply will take 7.8amps (if it is a resistive load) when the supply voltage is 12v and this is more than the power supply will deliver.

THE SOLUTION:
1. Use a 10 amp power supply, or

2. Use a 12v rechargeable battery and a multimeter with 10 amp capability, as shown in the diagram above.

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PROBLEM 3:

A reader in an electronics forum has built an amplifier but its output is very low because he has used a small transformer.
He asks: "Is it possible to hook two transformers together for a higher current?"
We are assuming he means IN PARALLEL. If they are connected IN SERIES, the output voltage will be too high for the amplifier.
Normally, parallel connection is not done because two transformers have to be IDENTICAL in the voltage they produce, so they share the load.
If the voltage is not the same, the transformer with the higher voltage will deliver most of the current.
Here is a circuit to connect two transformers and see if the amplifier produces a higher output:
If the transformers have AC output, they must be connected in parallel via a diode on one of the leads FOR EACH TRANSFORMER:
This is only a TEST SET-UP to determine if connecting the two transformers will improve the output of the amplifier.

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The Transistor Amplifier

Home

Save P1 as:
.doc (700kB .pdf (600kB)

Save P2 as:
.doc (1.6MB) .pdf (1.2MB)

See: 1- 100 Transistor Circuits
101 - 200 Transistor Circuits

P1 P2 P3 test

The Transistor Amplifier is available as a .pdf but this file is not updated as fast as the web page. New items are added on a daily basis as we get a lot of requests from readers to help design a circuit and explain how a circuit works.
We have not opted for covering transistor circuit design as found in most text books because there are many available on the web for free download.
We have decided to cover this topic in a completely different way, with a circuit to cover each explanation.
This way you will pick up all the pointers that the text books miss.
It's only after you start designing a circuit that you find out how little you have been supplied via conventional teaching and that's why our approach is so important.
If you look at the Indian magazines you will find faults and poor descriptions in almost every one of their circuits.
No only is the designer poorly informed but the technical editor of the magazine is unaware of the mistakes and the readers do not reply with corrections. It's total ignorance ALL AROUND.
The Transistor Amplifier article will help you understand some of the faults and how to avoid them.

TOPICS:

THE DIFFERENTIAL AMPLIFIER
or
LONG TAILED PAIR

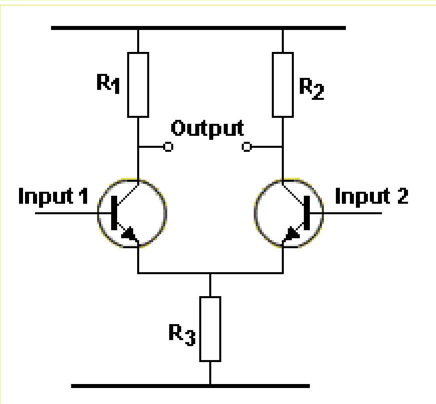


Fig 71ad

The **DIFFERENTIAL AMPLIFIER** is also called the "**Difference Amplifier"** or **long-tailed pair** (LTP), or **emitter-coupled pair,** because it amplifies the **difference** between the voltages on **Input 1** and **Input 2**. It is called a Long Tailed Pair because the emitter resistor has a high value. The circuit has the advantage of ONLY amplifying the signals on the Inputs. Any noise on the power rail is not detected on the output as both transistors will see this fluctuation and both outputs will either rise or fall and thus the output **will not change**.
Since the **Long Tailed Pair** does not pick up noise from the supply, it is ideal as a pre-amplifier as shown in the 60 watt amplifier in **Fig 71ae**:

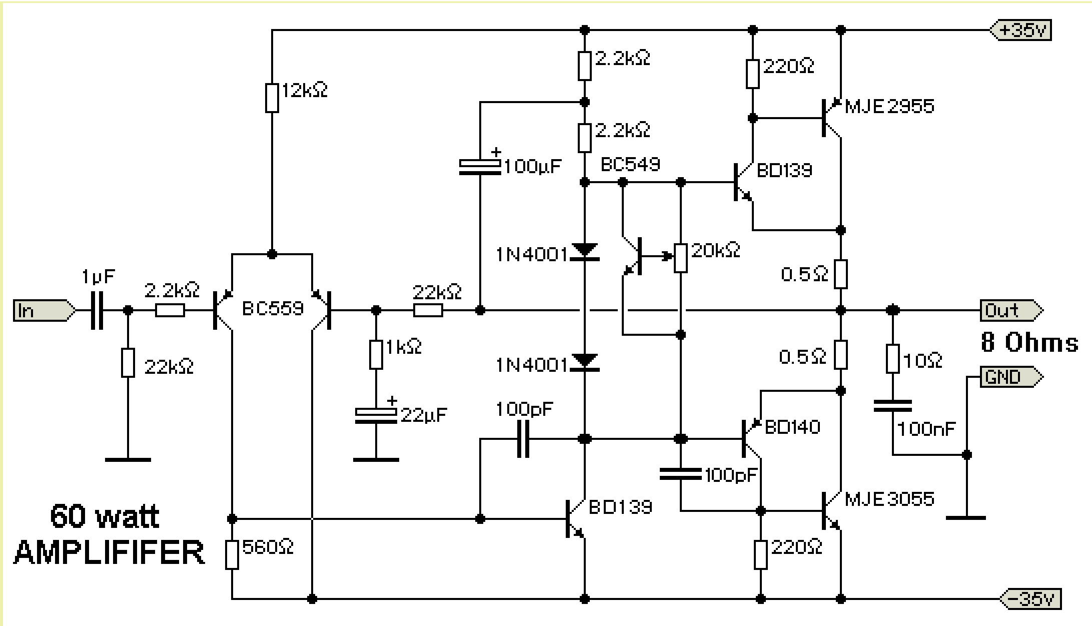


Fig 71ae

THE CONSTANT-CURRENT CIRCUIT

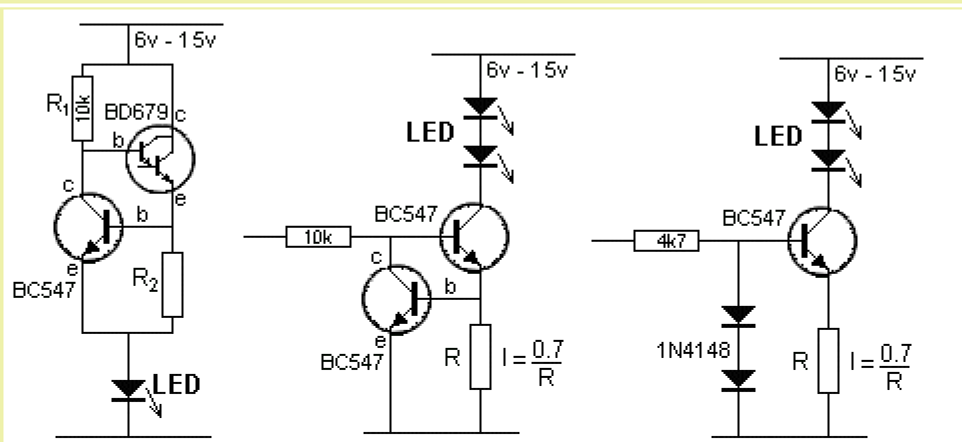


Fig 71a Constant-Current Circuits

The three circuits above provide a constant current through the LED (or LEDs) when the supply rises to 15v and higher. The second and third circuits can be turned on and off via the input line.

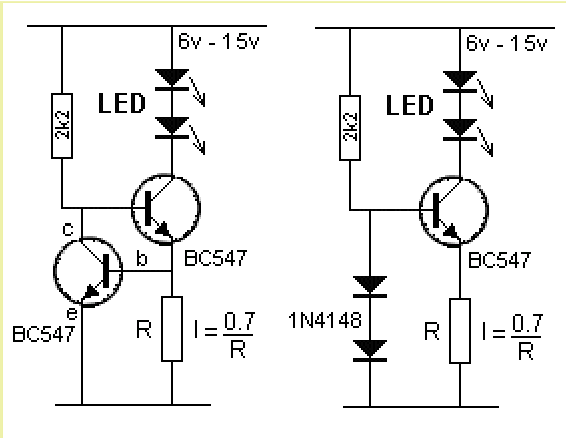


Fig 71b Constant-Current Circuit

The first circuit in **Fig 71b** is a constant-current arrangement, providing a fixed current to the LEDs, no matter the supply voltage.
This is done by turning on the top transistor via the 2k2 resistor. It keeps turning on until the voltage-drop across resistor **R** is 0.65v. At this point the lower transistor starts to turn on and current flows through the collector-emitter terminals and it "robs" the top transistor of current from the 2k2 resistor. The top transistor cannot turn on any more and the current flowing though R is the same as the current flowing through the LEDs and does not increase.

The second diagram in **Fig 71b** is also a constant-current circuit with the base fixed at:
0.7v + 0.7v = 1.4v via the two diodes.
The transistor is turned on via the 2k2 resistor and a voltage is developed across resistor **R**. When this voltage is 0.7v, the emitter is 0.7v above the 0v rail and the base is 1.4v. If the transistor turns on more, the emitter will be 0.8v above the 0v rail and this will only give 0.6v between base and emitter. The transistor would not be turned on with this voltage-drop, so the transistor cannot be turned on any more than 0.65v across the resistor **R**.

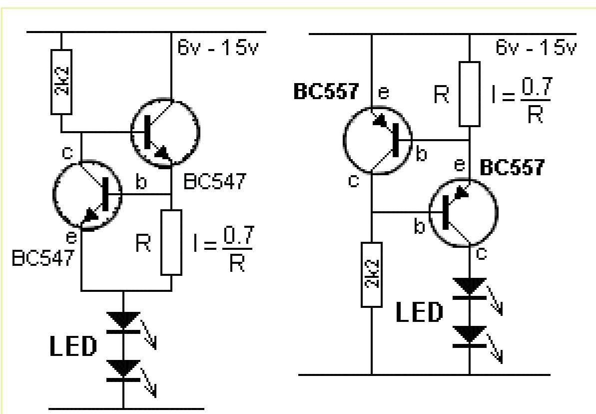


Fig 71ba Constant-Current Circuit

Fig 71ba shows two more constant current circuits "sourcing" the LEDs. The 7 constant current circuits give you the choice of either sourcing or sinking the LED current.

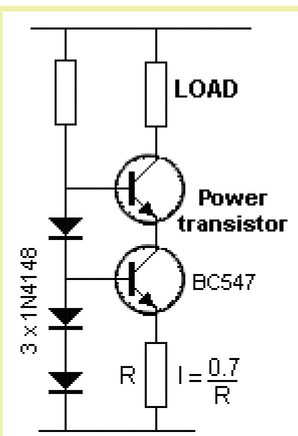


Fig 71bab Constant-Current Circuit for high voltage

If the supply voltage is high, the transistor controlling the current (BC547) will get hot and alter the current-flow.
Fig 71bab uses a POWER TRANSISTOR to dissipate the losses and the current-controlling transistor remains cold.

When the circuit turns ON, the current through R is zero and the voltage on the base of the BC547 turns it on fully. The voltage between collector and emitter is about 0.2v and this means the emitter of the power transistor is below the base of the BC547. The base of the power transistor is 0.7v above the base of the BC547 and the power transistor also turns on fully.
Current increases through R and when the voltage across R reaches 0.7v, The BC547 starts to turn OFF. The collector voltage rises and this starts to turn OFF the power transistor. This is how the current through the LOAD is limited by the value of R.

supply

THE CURRENT MIRROR CIRCUIT

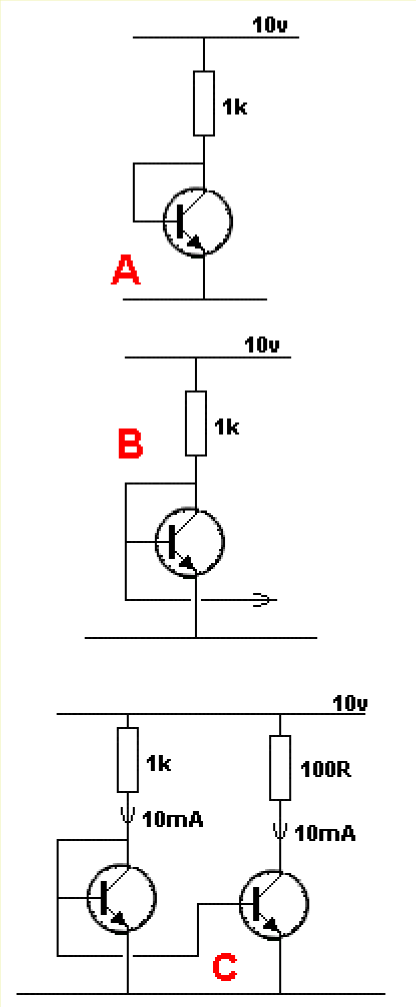


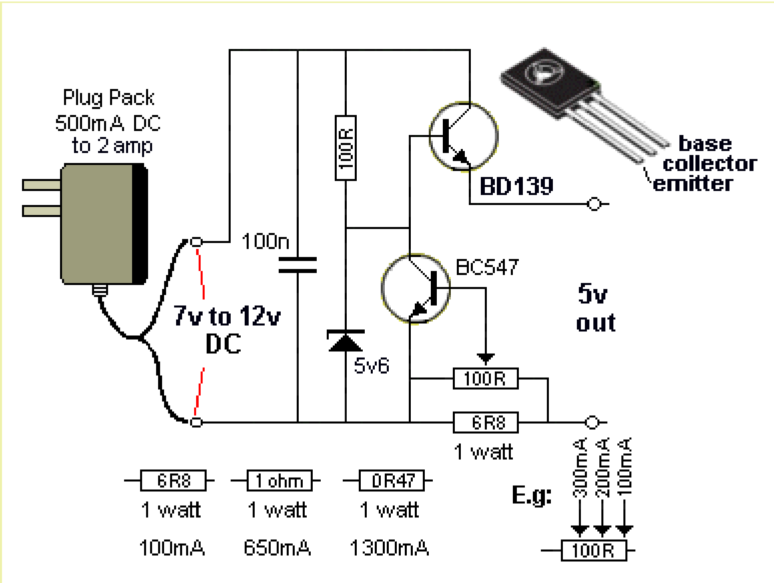
Fig 71bac Current Mirror Circuit

This is not a constant current circuit. It is a **CURRENT SOURCE** circuit. A **constant current** circuit means the current will not change if the supply voltage is increased or decreased. This circuit simply supplies a DC signal (in the form of a voltage) to another circuit so that the current in the original circuit is available in the second circuit and this is called a **current mirror** arrangement.
We start with diagram **A**.
The transistor is turned on because the base is connected to the collector. The collector can only rise to about 0.7v because it is connected to the base so that most of the supply-voltage appears across the load. This means the current through the load is known.
It can be determined by Ohm's Law: I =V/R.
Here's how the circuit works: When the circuit is turned ON, current flows through the resistor and through the base-emitter junction. This turns the transistor ON very hard and the current through the collector-emitter circuit increases. This reduces the voltage on the collector and as it decreases, the voltage on the base decreases and the transistor starts to turn OFF. In the end, the transistor is turned on to allow 10mA to flow through the collector-emitter junction due to the 10v supply and 1k resistor.
Suppose we instantly change the 1k for 100 ohms.
The transistor is only lightly turned ON and current though the collector-emitter is only 10mA. But the 100R will deliver 100mA and the extra current will flow into the base and turn the transistor ON harder. This will increase the current thorough the collector-emitter junction and rob the base of the extra current, however the current into the base will be higher than before because the transistor has to be turned on more to allow about 100mA to flow through the collector-emitter junction.
If we take a lead from the base of the transistor, as shown in fig **B** we can connect it to the base of an identical transistor and the second transistor will allow the same current to flow though the collector-emitter junction.
The result is circuit **C**. The current through the 100R resistor will be 10mA (normally it would be 100mA). The second transistor is only lightly turned on and allows 10mA to flow.

ADJUSTABLE CURRENT POWER SUPPLY

A reader requested a circuit for an **Adjustable-Current 5v Power Supply**.
In other words he wanted a power supply with **CURRENT LIMITING**.
This type of power supply is very handy so you can test an unknown circuit and prevent it being damaged.
For this design we will make the current adjustable from 100mA to 1 amp.
This circuit can be added to any power supply with an output of more than 7v. Our circuit requires at least two volts "head-room" for the voltage across the regulating transistor (the transistor that delivers the voltage and current) and about 0.5v for the current-detecting resistor.
The maximum current is set by the 100R pot and
This circuit delivers 5v when no current is flowing and the voltage gradually reduces. When the set

value of current as selected by the 100R pot is reached the output voltage will have dropped by 0.6v. This is the voltage developed across the current-sensing resistor and this voltage is detected by the BC547 to to start to reduce the output voltage. As soon as the maximum current is reached, the voltage falls at a faster rate and if the output is short-circuited, the current-flow will be as set by the pot.



ADJUSTABLE CURRENT POWER SUPPLY

The output voltage of this power supply can be increased by changing the voltage of the zener diode. The voltage of the plug pack must be at least 3v above the output voltage to allow the regulator transistor and current-detector resistor to function.

CONSTANT CURRENT

As soon as the load reaches the point where it takes the full current, the circuit turns into a **CONSTANT CURRENT** power supply.

VOLTAGE REGULATOR

Before we go to the **2-transistor Voltage Regulator**, we will explain how a voltage regulator works.
The basis of all voltage regulators is a diode.
A diode has a voltage characteristic. When a voltage is placed across its terminals, and the voltage starts at zero, no current flows through the diode until the voltage reaches 0.65v. As soon as it reaches 0.65v, current flows and as you increase the voltage, more current flows but the voltage across the diode remains at 0.65v. If the voltage is increased further, the current increases enormously and the diode will be destroyed.
This characteristic does not apply to a resistor. The voltage across a resistor will increase when the supply voltage increases and thus a resistor cannot be used as a Voltage Regulator.
We have selected 0.65v for this discussion as this is the characteristic voltage-drop for a normal silicon diode.
However germanium diodes and Schottky diodes have different characteristic voltage drops. On top of this, special diodes can be produced with higher voltages. These are called **ZENER DIODES**.
They all have the same characteristic. As soon as the specified voltage appears across the terminals of the diode, current starts to flow and if the voltage is increased too much, the diode will be damaged.
To prevent this, a resistor must be placed in series with the diode.
This is the basis of all voltage regulators.

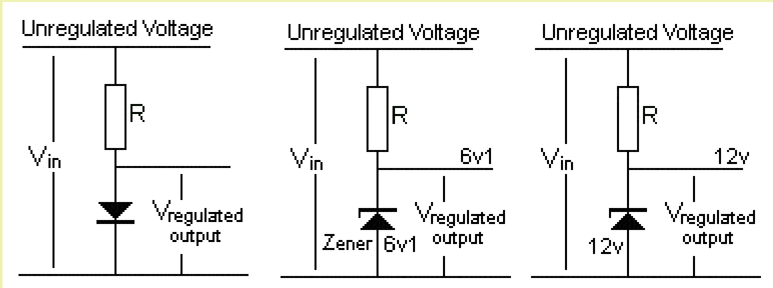


Fig 71be The Unregulated Voltage is regulated by the diode (zener)

In **Fig 71be**, the supply voltage is called the **UNREGULATED VOLTAGE** and it is connected to resistor R and a diode. The voltage at the top of the diode is called the **REGULATED VOLTAGE**.
The diode produces a fixed 0.65v and the zener produces a fixed 6v1 or 12v.
This circuit is called a **SHUNT REGULATOR** because the regulator is shunted (placed across) the load. [A Shunt is a load - generally a low-value resistor - placed across a component in a circuit to take a high current to either protect the other components or to test the circuit under high-current conditions.]
That's exactly what the diode or zener diode does.
It takes ALL THE CURRENT from the unregulated supply and and feeds it to the 0v rail. During this condition the circuit is 100% wasteful. All the wattage is being lost in heating resistor R and heating the diode.
The circuit is providing a fixed voltage at the top of the zener.
When a load is added to the circuit, it takes (or draws) current and this current comes from the current flowing though the zener.
The load-current can increase to a point where it takes nearly all the current from the zener.
If it takes more current than the zener, two things happen. Current stops flowing though the zener and the voltage on the top of the zener drops to a lower value. This is the point where the zener has **dropped out of regulation** and the circuit is no longer regulating.
In other words: A current is flowing into the regulator circuit and it is being divided into two paths: The zener path and the load path. The load path cannot be more than 95% or the regulator will drop out of regulation (the output voltage goes below the zener voltage).
Here's how the diode (or the zener) works: The zener is just like a bucket with a large hole in the side. As you fill the bucket, the water (the voltage) rises until it reaches the hole. It then flows out the hole (through the zener) and does not rise any further. When you draw current from the circuit it is the same as a tap at the bottom of the bucket and the water flows out the tap and not the hole. The pressure out the tap is the voltage of the zener.
The only disadvantage of this circuit is the voltage across the zener changes a small amount when the current through it changes.
The **SHUNT REGULATOR** is limited to small currents due to the fact that the load is taking the current from the zener.
The current can be increased by adding a buffer transistor to produce a **BUFFERED SHUNT REGULATOR** as shown in **Fig 71bf.** This circuit actually becomes a PASS TRANSISTOR arrangement.

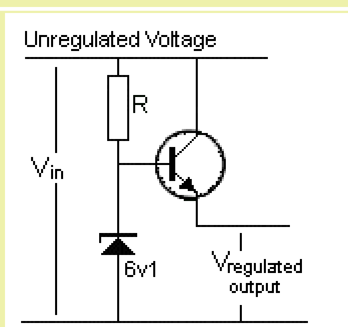


Fig 71bf Buffered Shunt Regulator
called a PASS TRANSISTOR Regulator

The transistor operates as an **amplifier** and if the DC gain of the transistor is 100, the output current of a Buffered Shunt Regulator can be 100 times more than a Shunt regulator.
See more circuits on the **Zener Regulator** and the **Transistor Shunt Regulator** and **Pass Transistor Regulator** in 101-200 Transistor Circuits. A very clever circuit to reduce ripple is called the **Electronic Filter**.

The whole concept of a regulator (removing the ripple while maintaining the required voltage) revolves around the voltage-drop across a diode and in **Fig 71bb**, the diode is replaced with the voltage-drop across the base-emitter junction of a transistor. This voltage-drop is fairly constant when a small current flows and this is the basis of the **Two Transistor Regulator:**

TWO TRANSISTOR REGULATOR

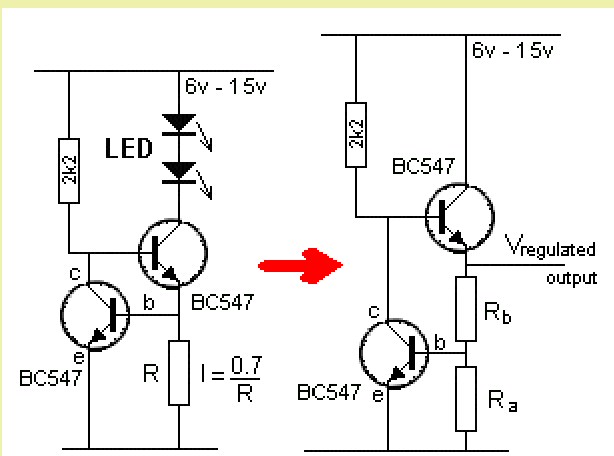


Fig 71bb

If we take the Constant-Current Circuit shown in **Fig 71b** above, and split resistor **R** into **R**a and **R**b, we produce an identical circuit with a completely different name. It is called a **TWO TRANSISTOR REGULATOR**.
The circuit will produce a smooth voltage on the output, even though the rail voltage fluctuates AND even if the current required by the output increases and decreases.
That's why it is called a REGULATOR CIRCUIT.
The current through Ra and Rb is "wasted current" so it does not have to be more than 1mA - enough to turn on the lower NPN transistor.
Ra and Rb form a voltage divider and when the join of the two resistor reaches 0.7v, the lower transistor turns ON.

The lower transistor forms a voltage-divider with the 2k2 to pull the top BC547 transistor DOWN so the voltage on the output is kept at the "design voltage" (the top transistor is an emitter follower). If the device connected to the output requires more current, the top transistor will not be able to provide it and the output voltage will drop. This will reduce the voltage on the base of the lower transistor and it will turn OFF slightly.
The voltage on the base of the top transistor will rise and since this transistor is an emitter-follower, the emitter will rise too and increase the output voltage to the original "design value."
Regulation is also maintained if the supply decreases (or increases).
If the supply decreases, the voltage on the base of the top transistor will fall and the output voltage will also fall.
The voltage on the base of the lower transistor will also fall and it will turn off slightly.
This will increase the voltage on the base of the top transistor and Vregulated will rise to the design

value. Both the supply and the load can change at the same time and the circuit will compensate. All we have to do is re-draw the circuit as a standard 2-Transistor Regulator as shown in **Fig 71bc** and you have covered the principle of its operation.

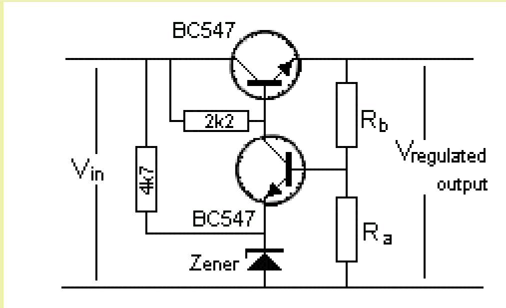


Fig 71bc
2-Transistor Voltage Regulator

THE TRANSISTOR AS AN AF AND RF DETECTOR

A transistor can be used as a "detector" in a radio circuit. The Detector stage in a radio (such as an AM receiver), is usually a crystal, but can be the base-emitter junction of a transistor.
It detects the slowly rising and falling audio component of an RF signal. This signal is further amplified and delivered to a speaker. A single transistor will perform both "detection" and amplification.
In **Fig 71bd**, the first transistor provides these two functions and the output is passed to the second transistor via direct-coupling.
The first two transistors provide enormous gain and a very high input impedance for the tuned circuit made up of the 60t aerial coil and 415p tuning capacitor. The signal generated in the "tuned circuit" is prevented from "disappearing out the left end" by the presence of the 10n capacitor as it holds the left end rigid.

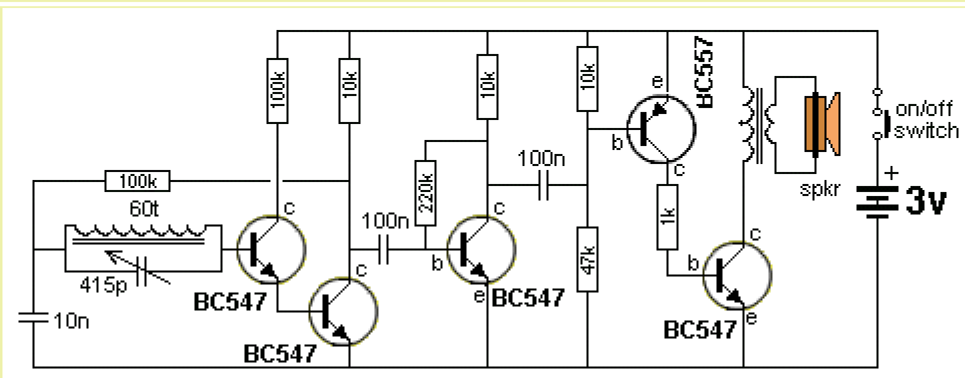


Fig 71bd 5-TRANSISTOR RADIO

THE COUPLING CAPACITOR

We have shown the coupling capacitor transfers very little energy when it does not get fully discharged during part of the cycle and this means it cannot receive a lot of energy to charge it during the "charging" part of the cycle.
This is a point that has never been discussed in any text books. It is the energy (actually the current - due to the difference in voltage between the two terminals of the capacitor) that flows into the capacitor that creates the flow of energy from one stage to the other. It is the "magnet on the door"

analogy described previously.
But the question is:
1. How much energy will a capacitor pass under ideal conditions?
2. How do you work out if a capacitor needs to be: 100n, 1u, 10u or 100u?

Without going into any mathematics, we will explain how to select a capacitor.
Many text books talk about the capacitive reactance of a capacitor. This is its "resistance" at a particular frequency.
But an audio circuit has a wide range of frequencies and the lowest frequency is generally selected as the capacitor will have the highest resistance at the lowest frequency.
We will select 200Hz as the lowest frequency for an amplifier.

A 100n will have a "resistance" of about 10k at 200Hz
A 1u will have a "resistance" of about 1k at 200Hz
A 10u will have a "resistance" of about 100R at 200Hz
A 100u will have a "resistance" of about 10R at 200Hz

A 100n capacitor at 200Hz is like putting a 10k resistor between one stage and the next.

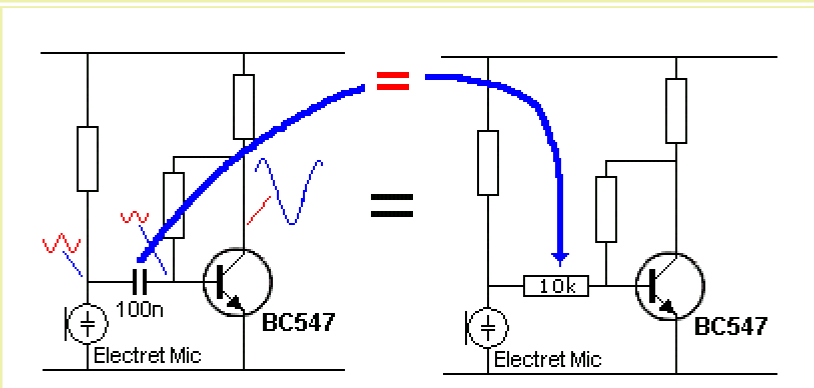


Fig 71c

A 1u capacitor at 200Hz is like putting a 1k resistor between one stage and the next.

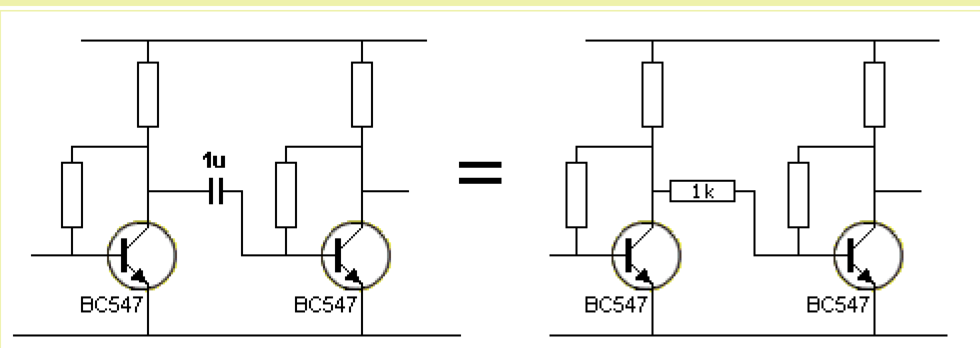


Fig 71d

A 10u capacitor at 200Hz is like putting a 100R resistor between one stage and the next and a 100u capacitor at 200Hz is like putting a 10R resistor between one stage and the next.
In other words, the resistor transfers the same amount of energy as the capacitor but the capacitor

separates the DC voltages - the capacitor allows the naturally-occurring voltages to be maintained.

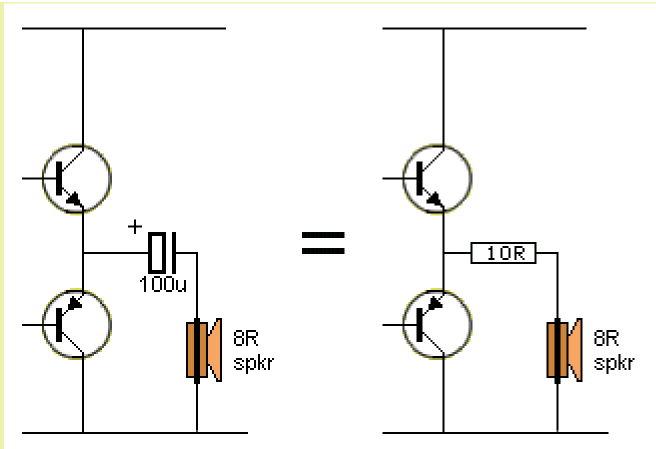


Fig 71e

The capacitive reactance of the 100u ranges from 10R to less than 1R (depending on the frequency being processed).

In **Fig 71d** you can see the "resistance" of a capacitor is very small compared to the LOAD resistance (the main component that determines the amount of energy that can be transferred from one stage to another and the impedance of the receiving stage - the component that determines the discharging of the capacitor). The "resistance" of a capacitor decreases as the frequency increases. Thus the "capacitive reactance" of a capacitor has very little effect on the transfer of energy from one stage to the next (when it is correctly selected). The major problem is not discharging the capacitor. It only transfers the maximum amount of energy when it is completely discharged.
When it is completely discharged, it acts like a "zero-ohm" resistor during its initial charging-cycle. This is called **INRUSH CURRENT** and can be ENORMOUS. This is the "plop" you hear from some amplifiers when they are turned ON. It is also the inrush current to a power supply. To reduce this enormous in-rush current, a small-value resistor is included in series with the input of the electrolytic(s) in the circuit (or power supply).

Let's go over this again:
The transfer of energy from one stage to another depends on 3 things:
1. The value of the LOAD resistor of the first stage. This resistor charges the capacitor. Its resistance should be as **low as possible** to transfer the maximum energy.
2. The value of the capacitor. It should be **as high as possible** to transfer the maximum energy.
3. The value of the input impedance of the receiving stage. It should be **as low as possible** to discharge the capacitor.

Let's take a 100n capacitor:
In the following circuit, a 100n capacitor separates an electret microphone from the input of a common-emitter stage.

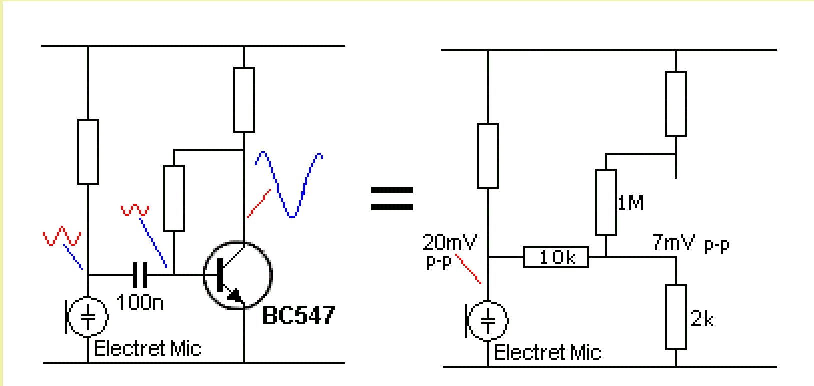


Fig 71f

The waveform on the output of the electret microphone is 20mV p-p (peak-to-peak). This amplitude passes through the 100n capacitor, which we have drawn as a 10k resistor, (to represent the capacitive reactance of the capacitor at 200Hz). The input impedance of the common-emitter amplifier is about 500 ohms to 2k. (500 ohms when the base current is a maximum and 2k when the base current is very small).

The capacitor and the input impedance form a simple voltage-divider, as shown in **Fig 71f.** When a 20mV signal appears on the input of the voltage divider, the voltage at the join of the two resistors will be about 3.3mV.

This is 3.3mV ON TOP of the 630mV provided by the 1M base-bias resistor.

This means about 16% of the waveform gets transferred to the base of the transistor. A common-emitter stage will have a gain of about 70, so 3.3mV input will create 230mV output. It's called a "swing" of 230mV or 230mV P-P (peak-to-Peak) or 230mV AC signal.

But most signals have a frequency of about 2kHz and the capacitive reactance of the capacitor will be about 1k. In this case the transfer will be 66% or 13mV and the output of the stage will be nearly 1v.

This is an ideal situation where the capacitor is being fully discharged.

The actual transfer of energy from one stage to another is much more complex than we have described, however you can see it involves the LOAD resistor, the size of the capacitor and the efficiency of discharging the capacitor.

The only way to see the actual result is to view the waveforms on a CRO (Cathode ray Oscilloscope).

INPUT AND OUTPUT IMPEDANCE

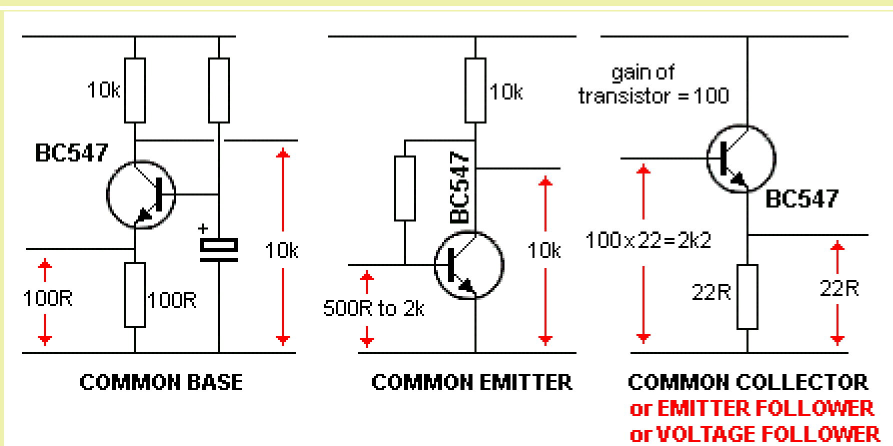
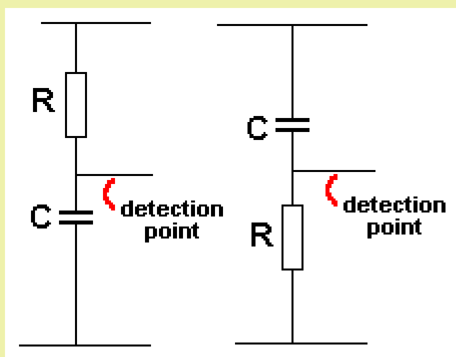


Fig 71g

Fig 71g shows each transistor stage has an input and output impedance. This really means an input and output resistance, but because we cannot measure the value with a multimeter, we have to find the value of resistance by measuring other things such as "waveform amplitudes" and then create a value of resistance, we call IMPEDANCE. The values shown are only approximate and apply to transistors called SMALL SIGNAL DEVICES. The values are really just a comparison to show how the different stages "appear" to input and output devices, such as when connecting stages together.
The input impedance of a common-emitter stage ranges from 500R to 2k. This variation depends on the type of transistor and how much the stage is being turned ON. In other words, the amount of current entering the base.
The value of 2k2 for the emitter-follower depends on the current entering the base.
These values are all approximate and are just to give an idea of how to describe the various values of impedance.

THE TIME DELAY

Also called the TRANSISTOR TIME DELAY or **TIME CONSTANT** or **RC Delay Circuit** or **TIMING CIRCUIT.**
A Delay Circuit is made with a capacitor and resistor in series:



The TIME DELAY circuit

These are the two components that create the **TIME DELAY**. No other parts are needed. When the value of the capacitor and resistor are multiplied together the result is called the **TIME CONSTANT** and when the capacitor value is in FARADS and resistor in OHMs, the result is SECONDS
To detect when the capacitor has reached about 63% of its final voltage, we need some form of detecting device, such as a transistor.
But the detecting device cannot "steal" any of the current entering the capacitor, otherwise the voltage on the capacitor will never increase or take longer to increase.
We know a transistor requires current for it to operate but a Darlington Pair (or Darlington) requires very little current, so the detecting device must be something like a Darlington.
The transistor plays no part in the timing (or TIME DELAY) of the circuit. It is just a detector.

The main secret behind a good TIME DELAY circuit is to allow the capacitor to charge to a high voltage and use a large timing resistor. This reduces the size of the capacitor (electrolytic) and produces a long time delay.
There are lots of chips (Integrated Circuit) especially made for timing operations (time delays).
Transistors (of the "normal" type - called Bipolar Junction) are not suited for long time delays.
Field Effect Transistors, Programmable Uni Junction transistors and some other types are more suited.
However a normal transistor can be used, as shown in **Fig 71h**.
The normal detection-point is 63% but you can make the circuit "trigger" at any voltage-level. The

value "63%" has been chosen because the voltage on the capacitor is increasing very little (each second) when it is nearly fully charged and waiting for it to reach 65% may take many seconds. Trying to detect an extra 10% or 25% is very hard to do and since it takes a long time for the voltage to rise, the circuit becomes very unreliable and very inaccurate. That's why 63% has been chosen.
See also Integration and Differentiation. The same two components (a resistor and capacitor) can be used for a completely different purpose. That's the intrigue of electronics.

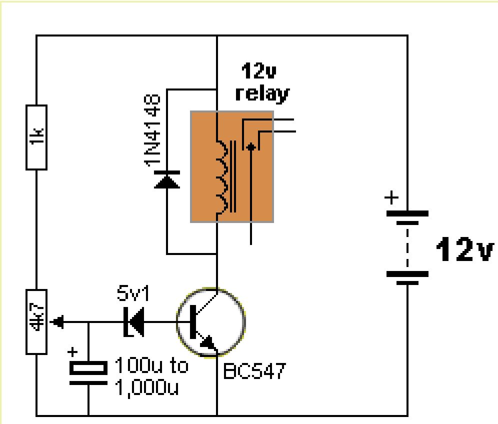


Fig 71h

Fig 71h shows a **TIME DELAY** circuit. This circuit does not wait for the capacitor to charge to 63% but it detects a voltage of 5v1 + 0.7v = 5v8.
The detecting circuit is made up of the 5v1 zener and base-emitter junction of the transistor.
These two components create a high impedance until a voltage of 5v8 because the zener takes no current until its "characteristic voltage" has been reached.

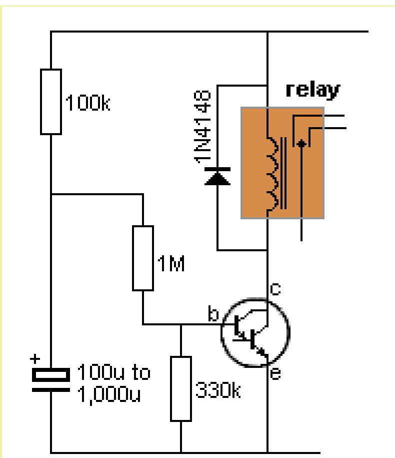


Fig 71j

Fig 71j shows a Time Delay Circuit. The 100k is the time delay resistor. The 1M is the "sense resistor" and the the 330k is the voltage divider resistor.
The base of the Darlington transistor detects 1.4v and the 1M/330k produces a voltage divider that requires 3 x 1.4v = 4.2v on the electrolytic. The 1M, 330k and transistor provide a fairly high impedance detecting circuit that does not inhibit the charging of the capacitor.
The circuit requires a supply of 12v.

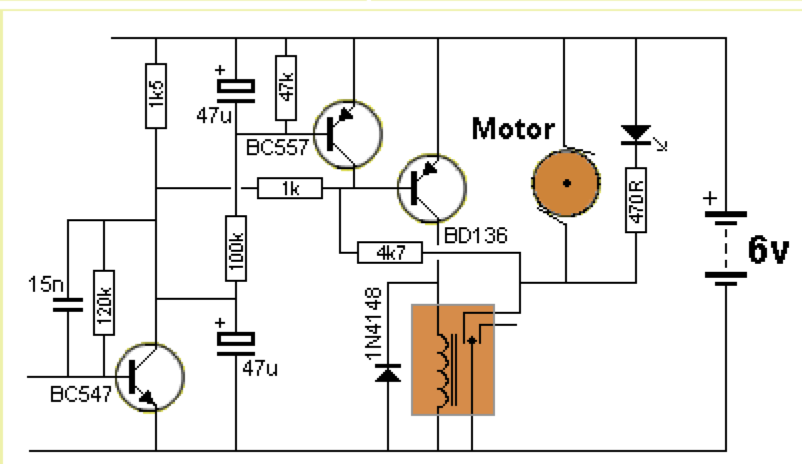


Fig 71k

Fig 71k shows two **Time Delay Circuits** as well as a latching circuit (the 4k7 resistor), a buffer transistor (BD136) and a high frequency filter (the 15n capacitor).
When the circuit is turned **ON**, the relay is not energised. The signal on the base of the first transistor has any high frequency component removed by the 15n capacitor (see below for the effect of a filter on a signal).
The lower 47u is fully charged via the 1k5 a very short time after the circuit is turned on and the output of the first transistor discharges this electrolytic very quickly when it receives a signal.
This turns **ON** the BD136 transistor via the 1k resistor and the relay is energised.
The output of the relay is connected to a 4k7 resistor and this resistor takes over from the effect of the first transistor to keep the relay activated.
If the input signal continues, the top 47u starts to charge and after about 2 seconds, the BC557 transistor turns **ON** and removes the emitter-base voltage on the BD136. This turns the relay **OFF**.

BACK EMF

In some circuits using a relay, you will find a diode has been placed across the coil.
When the relay is turned OFF, it produces a voltage in the opposite direction that can be much higher than the voltage of the supply. This means the voltage appearing on the collector will be higher than some transistors can withstand and they will either zener and absorb the energy or be damaged due to the excess voltage. The diode across the coil is connected so the voltage flows through it and the transistor is protected.
This voltage is called BACK EMF and only occurs when the relay is turned off suddenly when full current (or near full current) is flowing.
The size of the back EMF is due to the number of turns on the coil and the metal in the (magnetic) core. It can be 10 times or even more than the supply voltage and the diode will reduce this to about 0.7v.
Figs 71h,j and k above show a diode across a relay to remove the back EMF and protect the transistor.

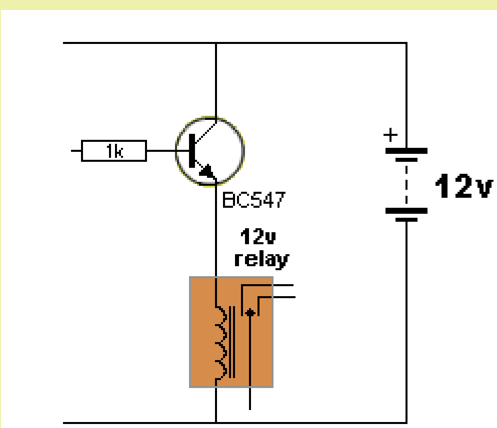


Fig 71m

Figs 71m shows a relay connected in the emitter of a transistor. This configuration is called an emitter-follower. When the transistor turns off, the relay is de-energised and a back-voltage is produced.
The voltage on the top of the relay becomes less than 0v and this pulls the emitter DOWN. This has the effect of turning ON the transistor and for a tiny fraction of a second, the effect of the relay is cancelled by a flow of current through the transistor. This prevents a high back-voltage being produced and thus a diode is not needed.

One point about emitter-follower designs:
The voltage on the relay is less than 12v due to the 0.7v between the base and emitter and the base will be lower than 12v by as much as 1v. Compare this with the common-emitter driver where the collector-emitter drop will be as low as 0.4v.

Back EMF is also produced by motors and is known as "commutation noise." This "noise" can also be suppressed via a capacitor and/or small inductors in the leads. The size of the voltage must be measured when the circuit is operating as it is a "spike" and this spike will puncture a semiconductor (such as a transistor).
Back EMF is also produced by coils, called INDUCTORS. An inductor is also called a choke.
When a piezo is placed across an inductor, and a signal is delivered to the parallel-pair, the piezo will detect the high-voltage (Back EMF) and produce a very load output. The inductor produces the high voltage when the signal is turned off sharply. The magnetic flux collapses and produces a very high

reverse voltage. A typical circuit that takes advantage of this high voltage is the: Wailing Siren

HIGH FREQUENCY "NOISE"

Before we move on to the next phase of this discussion, there is one interesting point that needs covering.
When a circuit has a number of amplifying stages, there is always a possibility of noise being generated in one of the transistors in the "front-end" (the first or second stage in the amplifier) and this is amplified by the stages that follow. This is the case with the Hearing Aid Amplifier in **Fig 69**.

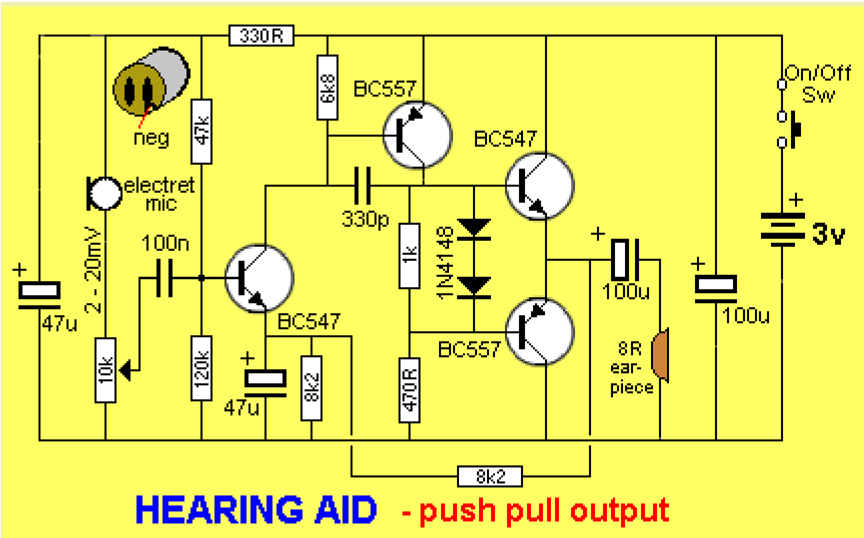


Fig 69.

The 330p between the base and collector of the BC557 removes high-frequency noise. If the 330p is removed a 1MHz waveform is generated in the front-end and amplified by the stages that follow. This noise cannot be heard but is visible on a CRO (Cathode Ray Oscilloscope) and causes the circuit to take extra current. The 330p capacitor provides **NEGATIVE FEEDBACK** to remove the waveform completely.

FILTERS

We have studied circuits that use components to produce NEGATIVE FEEDBACK. The first circuit we studied was the self-biased common-emitter stage. The base-bias resistor provided negative feedback to set the voltage on the collector.
Any component (resistor or capacitor) connected between the output and input of a stage produces NEGATIVE FEEDBACK.
A **resistor** connected between the output and input produces about the same amount of feedback no matter what frequency is being process by the amplifier.
But a **capacitor** provides more feedback as the frequency increases. That's because the effective "resistance" of the capacitor decreases as the frequency increases.
This feature can be used to "kill" the amplitude of high frequencies and thus only allow low frequencies to be amplified.
It can also be used to only allow high frequencies to be amplified. When it is used to couple two stages, a **low-value** capacitor will only allow high frequencies to pass from one stage to the next.
By using a resistor in series with a capacitor, the effect of the capacitor can be controlled.
Using these facts, we can design circuits that will amplify low frequencies or high frequencies. This type of circuit is called a FILTER.
A Filter can be given a number of names. Here are a few:
Active Filter contains a transistor or op-amp in the circuit
High Pass Filter suppresses or rejects the low frequencies Only the high frequencies appear on the output
Low Pass Filter suppresses or rejects the high frequencies Only the low frequencies appear on the output
Notch Filter: A Filter that rejects or suppresses a narrow band of frequencies.

To understand how a filter works, you need to know "**HOW A CAPACITOR WORKS**."

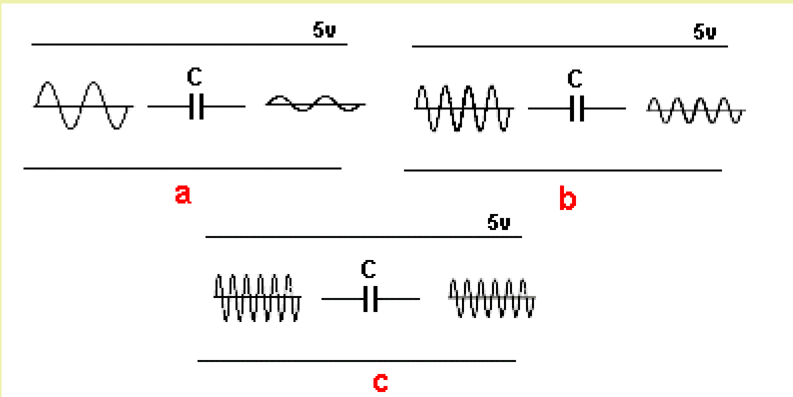


Fig 72a.

Fig 72a shows a capacitor with a low-frequency signal entering the left terminal.
The output amplitude from the capacitor in diag a will be small because the capacitor is able to charge and discharge as the signal rises and falls.
As the frequency of the signal increases, the output increase in amplitude because the capacitor does not have enough time to charge and discharge and thus it does not "absorb" the amplitude of the signal.

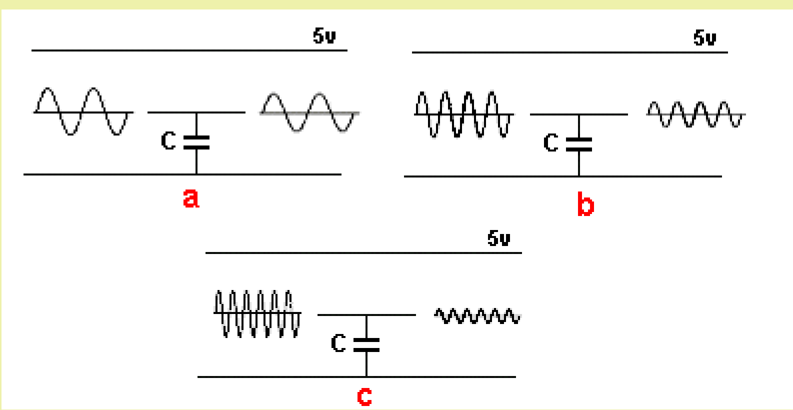


Fig 72b.

Fig 72b shows a capacitor connected between the "signal line" and 0v rail. When a low-frequency signal is on the "line," the capacitor has little effect on attenuating (reducing) the amplitude, as shown in diag **a** because the capacitor charges and discharges just like pushing a "shock absorber" up and down **slowly**.
As the frequency of the signal increases, it is reduced in amplitude because the signal is trying to charge and discharge the capacitor very quickly and it takes **energy** to do this and the energy is coming from the signal.

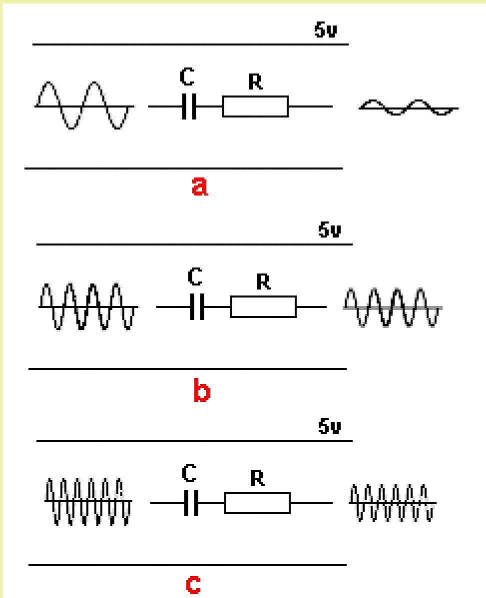


Fig 72c.

Fig 72c Fig a shows a capacitor and resistor connected in series on the "signal line." With a low-frequency signal, the capacitor reduces the amplitude because most of the signal is absorbed by the capacitor charging and discharging.
As the frequency increases (**fig b**), the output will be reduced by a smaller amount because the capacitor has less time to charge and discharge and less time to "absorb" the signal.
As the frequency is increased further **(fig c)**, the resistor starts to have an effect on reducing the amplitude because these two components are connected to other components in a circuit and a higher frequency has a higher energy and more of this energy gets lost in the resistor - thus reducing the amplitude slightly.
In addition, the capacitor is already charging and discharging as quickly as possible and it is transferring as much of the signal as possible. It is only the resistor that is creating the attenuation at high frequencies.
It does not matter if the capacitor or resistor is placed first or last, the attenuation is the same.

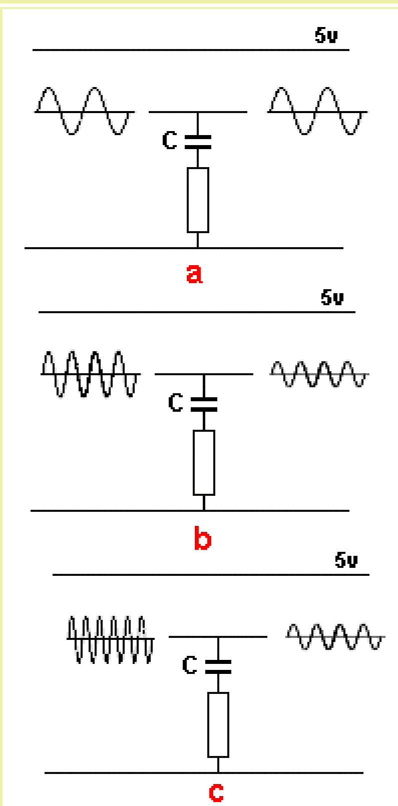


Fig 72d.

Fig 72d Fig a shows a capacitor and resistor connected in series between the "signal line" and 0v rail. With a low-frequency signal the capacitor can charge and discharge and the voltage across it will rise and fall so the effect on the amplitude of the signal is minimal.
The resistor has very little effect on reducing the amplitude.
The top plate of the capacitor rises and falls with the signal and the bottom plate rises and falls very little.

As the frequency increases, the capacitor cannot charge and discharge fast enough and more of the energy of the signal goes into charging and discharging it. The top plate of the capacitor is rising and falling very quickly and this is making the lower plate rise and fall a small amount. This puts a small current though the resistor and this has an effect on reducing the amplitude.
The amplitude of the output is reduced as shown in Fig **b**.

As the frequency is increased further as shown in diag **c**, the top plate of the capacitor is rising and falling as fast as it can and the lower plate is rising and falling too. This puts most of the amplitude-loss in the resistor but the signal is not reduced any more.
It does not matter if the capacitor is above or below the resistor, the attenuation is the same.

Once you have a concept of the way a capacitor reacts to a high and low frequency, you can see how a circuit will pass or prevent (attenuate) a signal.
There are many different types of filters and they are all designed to improve the output of a poor signal, such as removing background "hiss" or "rumble" in audio recordings.
The following two circuits show the effect of adding capacitors and resistors between the output and

input:

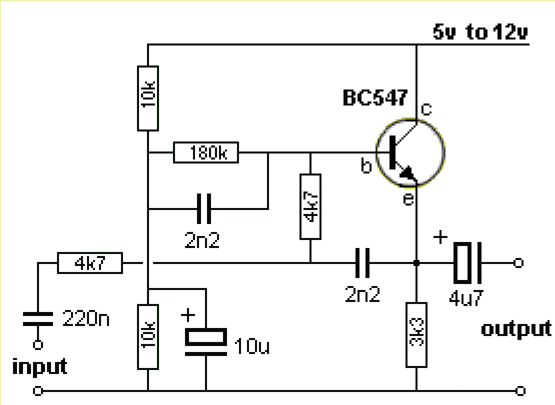


Fig 72e.

Fig 72e is a low-pass filter that provides unity voltage gain to all frequencies below 10KHz, but it rejects all frequencies above 10KHz at 12dB per octave. It is used to remove high frequency noise from audio recordings.

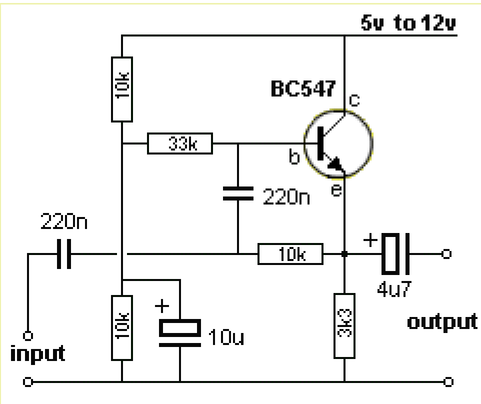


Fig 72f.

Fig 72f is a high-pass filter that provides unity voltage gain for all frequencies greater than 50Hz. However, it provides 12 dB per octave rejection to all frequencies below 50Hz. It is used to remove low frequency noise from audio recordings.
The transistor is configured as an emitter-follower biased at about half the supply value by the low-impedance junction formed by the top 10k resistor and the lower 10k in parallel with the 10u electrolytic.
Negative feedback applied through the filter network of the 33k and 220n and the 10k and 220n creates an *active* filter response.

THE "DIGITAL" STAGE - or Digital State also called the DIGITAL CIRCUIT

All the circuits and stages we have discussed have been amplifiers for audio signals.
However there is another signal that can be processed via an amplifier. It is called a digital signal or "Computer" signal. It is a signal that turns a transistor ON fully or OFF fully.
The simplest example of a digital circuit is a torch. The globe is either ON or OFF. But a torch does not have any transistors. We can simply add a transistor and the circuit becomes DIGITAL CIRCUIT.
A Digital Circuit has 2 STATES: ON and OFF. It is never half-ON or half-OFF.

The secret to turning a transistor ON fully is base current. If you supply enough base current the transistor will turn ON FULLY.
The Digital Circuit is the basis of all computers. It produces an outcome of "0" when not active or "1" when active. This is called POSITIVE LOGIC.

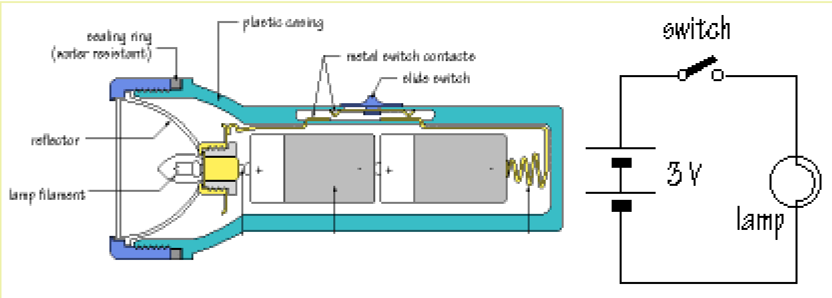


Fig 72.

Fig 72. A TORCH is an ON-OFF circuit.
A Digital circuit is an ON-OFF circuit.

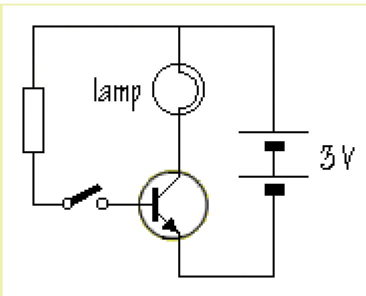


Fig 73.

Fig 73. This is the simplest DIGITAL CIRCUIT. The globe illuminates when the switch is closed.

Two reasons why a Digital Circuit was invented:
1. It produces either "0" or "1" (LOW or HIGH) and these are accurate values. By combining millions of "digital circuits" we can produce counting and this is the basis of a computer.
2. When a circuit is OFF, it consumes no power. When a circuit is fully ON the transistor also consumes the least power. This is because the globe is illuminated brightly and the transistor remains cool - as it has the lowest voltage across it.
The "ON" "OFF" states are called LOGIC STATES or DIGITAL STATES and when two transistors are put together in a circuit with "cross-coupling" they alternately flash one globe then the other.

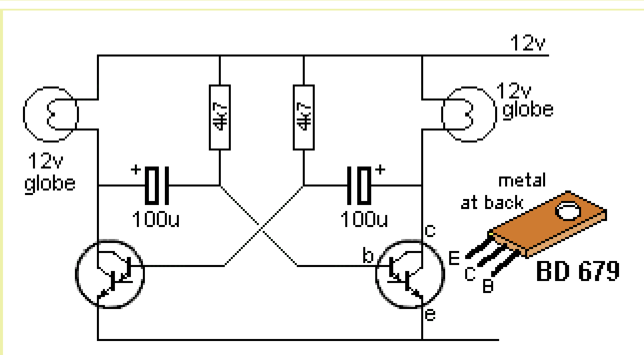


Fig 74.

Fig 74. This circuit is called a **FLIP FLOP** or **ASTABLE MULTIVIBRATOR**.
(AY-STABLE - meaning not stable)

THE TRANSISTOR AS A SWITCH

Using a transistor as a switch is exactly the same as using it in **DIGITAL MODE** or in a **DIGITAL CIRCUIT** or in a **LATCH CIRCUIT** or any other circuit where the transistor changes from OFF state to

ON state VERY QUICKLY.
A transistor in this type of circuit is called a **SWITCHING TRANSISTOR** and it may be an ordinary audio transistor but it is called a switching transistor when used in a switching circuit.
The two Darlington transistors in **Fig 74** are SWITCHING TRANSISTORS and the circuit is an **ASTABLE MULTIVIBRATOR.**
One of the most common circuits is used to activate a relay. A relay must be turned ON or OFF. It cannot be half-on or half-off. The transistor changes from OFF to ON very quickly. It is called a switching transistor.
All transistors used in a **DIGITAL CIRCUIT** are switching transistors. **DIGITAL CIRCUITS** or **DIGITAL LINES** are either **HIGH** or **LOW**.
When a digital transistor is turned **ON** (saturated) the output is LOW. When a digital transistor is **OFF** the output is HIGH. The output is taken from the collector of a common-emitter stage.
This is called two MODES of operation. **ON** and **OFF**.
Any circuit that operates in **TWO MODES** is called a **DIGITAL CIRCUIT**.

DRIVING A RELAY

Any circuit that drives (powers) a relay is essentially a DIGITAL CIRCUIT. Sometimes the driving circuit can gradually turn ON and when the collector current is sufficient, the relay pulls-in.
When the collector current falls to a lower value, the relay drops-out.
We like to think of the driver stage as a digital stage so that we guarantee the relay will pull-in and drop-out.
Here's an important feature that has never been mentioned before:
A relay must pull in quickly and firmly so the contacts close with as much pressure as possible. This prevents arcing when closing and opening and ensures a long life for the relay.
That's why the driver circuit should be an ON-OFF or DIGITAL design.
The following circuits are NOT high-speed, but will activate a relay successfully.

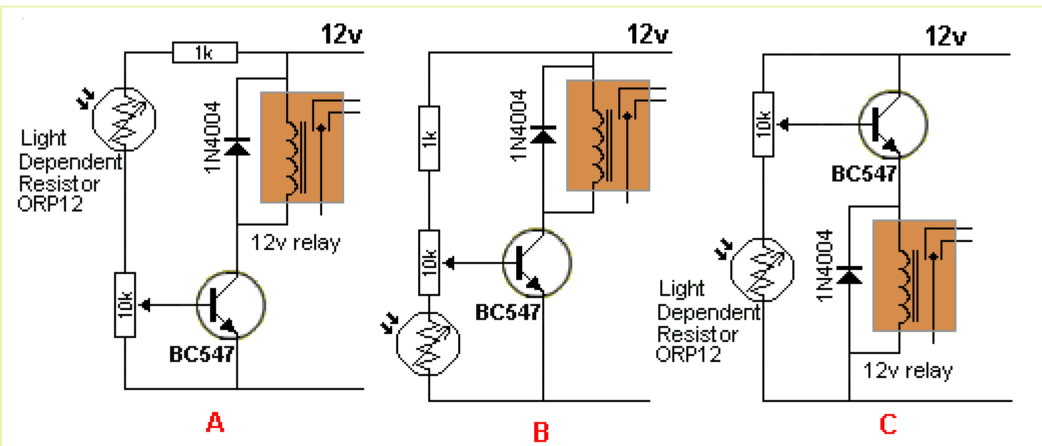


Fig 74a.

Circuit **A** activates the relay when light falls on the LDR. The level of illumination can be adjusted by the 10k pot.
Circuit **B** activates the relay when the illumination reduces. The level can be adjusted by the 10k pot.
Circuit **C** is an emitter follower and although it works in a similar way to circuit B, the voltage on the collector is less than 12v by about 1v and this creates extra loss and added temperature-rise in the transistor.

LATCH CIRCUIT - an SCR made with transistors

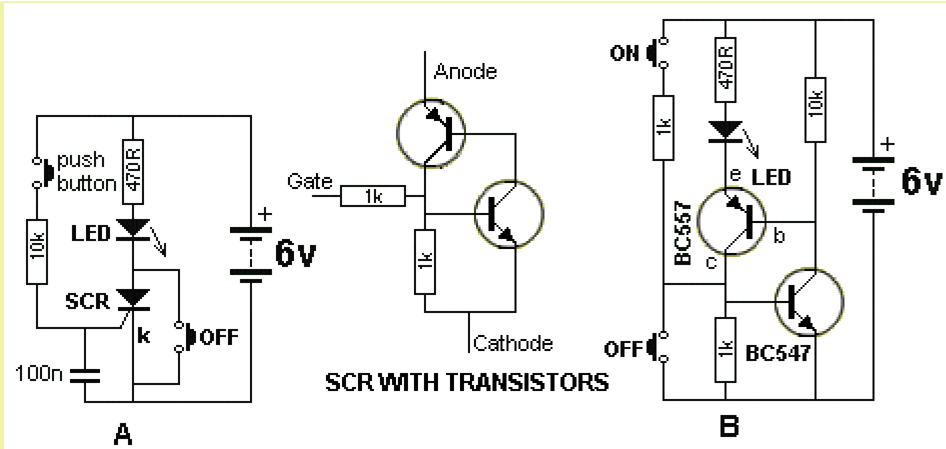


Fig 75. Latch Circuit

Fig 75. Circuit B is a LATCH. The two transistors instantly change from the OFF state to the ON state. This is also classified as a DIGITAL CIRCUIT. The circuit can also be called an SCR made with transistors. Circuit A shows an SCR in action. The top switch turns the SCR ON and it stays ON when the button is released. To turn the SCR off, the lower switch is pressed.
The SCR in circuit A produces a 'LATCH.'
The SCR can be replaced with two transistors as shown in circuit B.

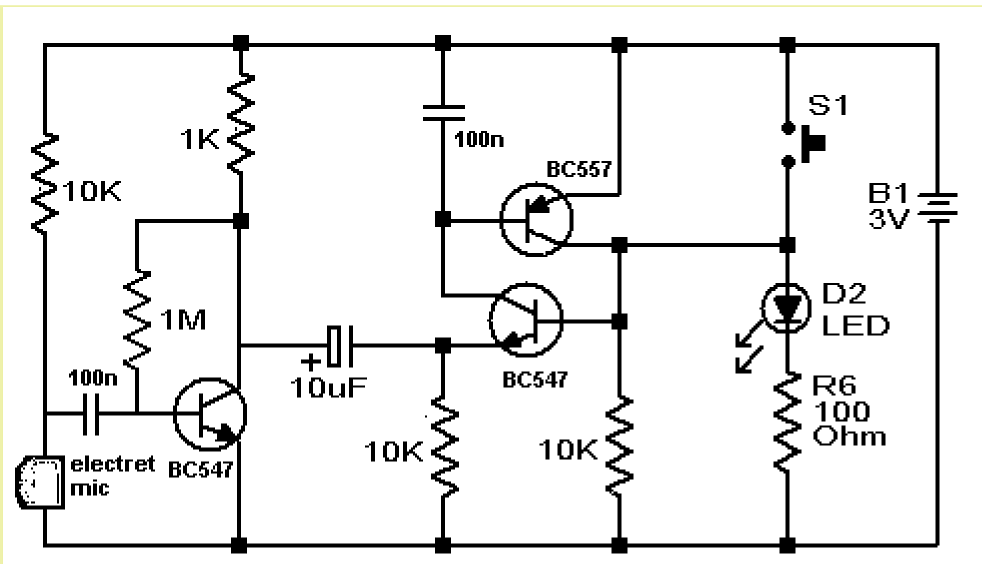


Fig 75aa. Latch Circuit

Fig75aa is a LATCH and the PNP/NPN transistors are "latched-on" by pressing S1. The circuit will also turn on with a resistor as high as 15k across S1 as we only need to put 0.6v on the base of the BC547 transistor. The 10k on the base forms a voltage divider and this determines the resistance of the "turn-on" resistor. The emitter of the BC547 transistor does not move when this voltage is applied and the collector of the BC547 pulls the base of the BC557 down to turn the PNP transistor ON. This action takes over from the 15k resistor and the two transistor remain ON.
The base of the BC547 is pulled to nearly rail voltage and the emitter is 0.6v lower. The 10u electrolytic charges to cater for the voltage-difference between the collector of the first transistor and the voltage on the emitter of the BC547.
When the first transistor turns on, the voltage on the collector reduces and this pulls the positive lead of the 10u towards the 0v rail.
The negative lead of the 10u cannot fall as it is connected to the emitter of the BC547.

This means the 10u discharges and when the first transistor turns off, the positive lead rises and takes the negative lead with it. This reduces the voltage on the emitter of the BC547 and the transistor turns OFF.
This is how the LED turns off.
Further blowing into the microphone will make the emitter lead of the BC547 rise and fall and this will make the LED flicker, just like trying to blow out a candle.

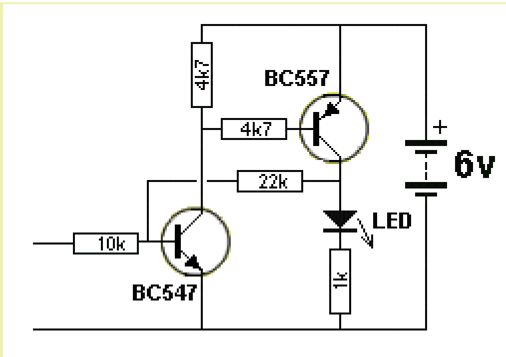


Fig 75a. Latch Circuit

Fig 75a. This circuit is a LATCH. The two transistors instantly change from the OFF state to the ON state when the input voltage rises above 0.6v
The 22k **POSITIVE FEEDBACK** resistor keeps the circuit **ON** when the input voltage is removed.
The 6v supply must be removed to turn the LED off.

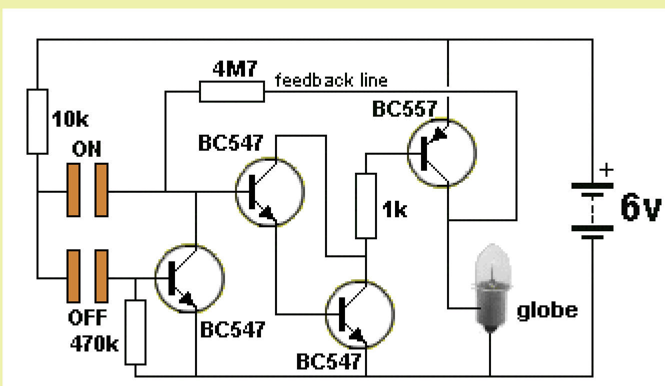


Fig 76. Touch Switch

Fig 76. This is a circuit of a TOUCH SWITCH. Touching the "ON" pads turns ON the second and third transistors as they are a SUPER-ALPHA PAIR or DARLINGTON arrangement and have a very high input impedance and very high gain. The output of this pair goes to a PNP transistor that amplifies the 5mA current from the Darlington to deliver 250mA to the globe.
A feedback line from output to input via a 4M7 keeps the circuit ON when your finger is removed and provides a "Keep-ON" voltage (and current).
The first transistor removes this **"Keep-ON" voltage and current** when a finger is placed on the OFF pads. .

How can you tell a **DIGITAL CIRCUIT** from an **ANALOGUE CIRCUIT?**
1. Absence of capacitors. There are **NO** capacitors in a **DIGITAL CIRCUIT.**
2. A switch or push-button will be activating the circuit.
3. The circuit will be driving a **DIGITAL** or **ON - OFF** item such as a relay or globe.

The two states of a transistor in a **DIGITAL CIRCUIT** are: OFF - called "**CUT-OFF**" and ON - called "'**SATURATION**."
To saturate a transistor the base current is simply increased until the transistor cannot turn on any more. In this state the collector-emitter voltage is very small and the transistor can pass the highest current and the losses (in the transistor) are the lowest.

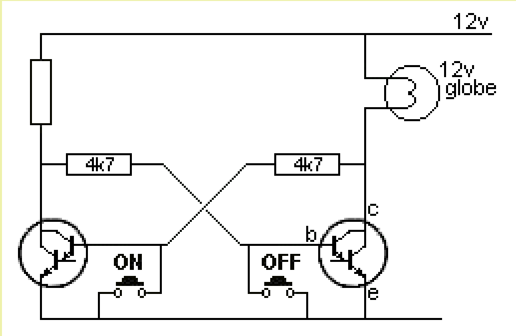


Fig 77.

Fig 77. This circuit has only two states. ON and OFF. The ON button turns off the first transistor so the second transistor turns the globe ON.
This is called a TOGGLE ACTION and the circuit is a BINARY CIRCUIT or BISTABLE CIRCUIT called a BISTABLE SWITCH or a bistable of the MULTIVIBRATOR family (**BISTABLE MULTIVIBRATOR**).
It can also be called a LATCH as it stores **one bit of information** and is the basis of a COMPUTER.

ILLUMINATING A GLOBE (Lamp)

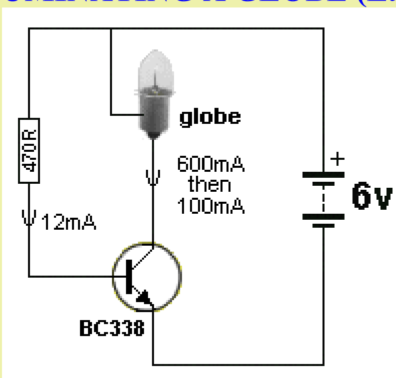
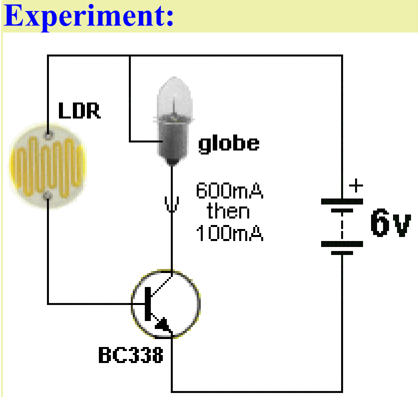


Fig77a. The base needs 12mA to "turn on" the globe

Illuminating a globe is not easy. A globe (lamp) takes 6 times more current to get it to start to glow because the filament is cold and its resistance is very low.
For instance, if a lamp requires 100mA, it will take 600mA to get it to start to glow.
This means the transistor must be capable of delivering 6 times more current and when the filament is glowing, the current will reduce to 100mA.
This means a transistor capable of delivering 800mA (BC337, BC338) will be sufficient for the job, however the gain of the transistor will have to rated at 50 because the current is getting near to the maximum.
The base current will have to be 600/50 = 12mA.
You need to supply the base with 12mA and the lamp will illuminate. When the lamp is glowing, the transistor only needs about 1-2mA, however it is difficult to reduce the current to the base and if the 12mA is supplied to the transistor, it simply means that 2mA will be used by the transistor and 10mA will pass through the base-emitter junction and be wasted.

Experiment:



Shine a light on the LDR and the globe will gradually get brighter.

You can change the 470R in the diagram above for an LDR (Light Dependent Resistor) and watch the globe illuminate.
The LDR chosen for the experiment has a resistance of 300k when in the dark and about 100 ohms when a bright light is shone on it. Do not shine a light too close to the LDR as its resistance will be so low that a very high base current will flow.
If the circuit does not work, the globe requires more than 600mA to get it to start to glow or 100mA when fully illuminated.

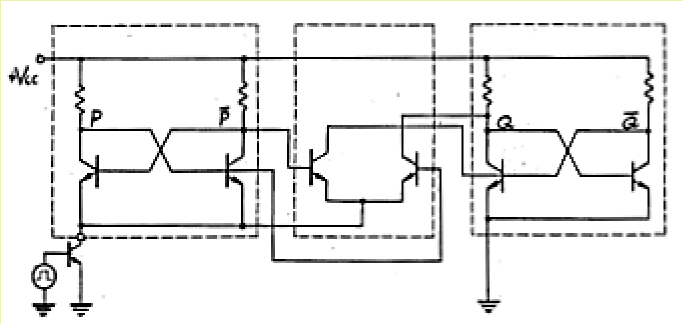


Fig 77b.

Fig 77b. This is part of a counting circuit and since it takes many transistors to create a circuit to count to "2" it is not practical to make it using discrete components. That's why INTEGRATED CIRCUITS were invented where dozens, then hundreds then thousands then millions of transistors are connected to produce counting chips and "bit-storing chips" and many other requirements.

Before we cover our next type of circuit, we will explain a 2-transistor directly-coupled arrangement from Figs 52 and 66. It is interesting as it can be used as a digital circuit or an analogue circuit.

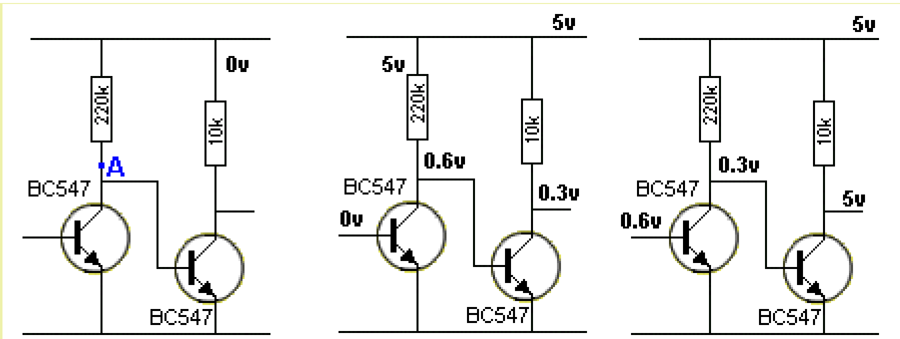


Fig 78.

Fig 78. Two facts to note:
1. Point "A" never rises above 0.6v as it is connected to the base of the second transistor.
2. When the first transistor is turned ON, the collector-emitter voltage is 0.3v and the second transistor is OFF - this is because the base of the second transistor needs 0.6v to turn ON.
In other words, when one transistor is **ON** the other is **OFF**. There is a very brief change-over point where the first transistor turns ON a little more and the second transistor turns OFF a very large amount. If you can find and maintain this change-over point, the two transistors will work in analogue mode with high gain but if you pass this point very quickly, the two transistors will operate as a switch in DIGITAL MODE.
We can turn this circuit into a DIGITAL CIRCUIT. The secret to doing this is FEEDBACK and the name of the circuit is a **SCHMITT TRIGGER:**.

THE SCHMITT TRIGGER

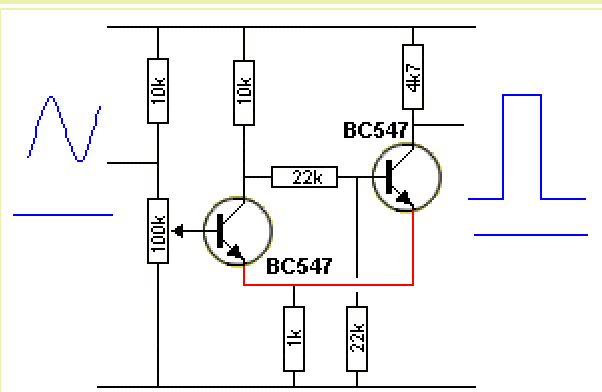


Fig 79a. Schmitt Trigger Circuit

Fig 79a. A **Schmitt Trigger** takes a slowly rising or falling voltage and turns it into a fast-acting ON-OFF signal. The secret is the feedback line shown in red.
The circuit can also be called a "sinewave-to-squarewave generator."
When the input is LOW the output is LOW.
It is a form of bi-stable multivibrator.
The distance between the lower voltage and the upper voltage (at which the circuit changes state) is called the **HYSTERESIS GAP**. This can be widened or narrowed via the 1k resistor (the 100k pot needs to be re-adjusted when the 1k is changed).

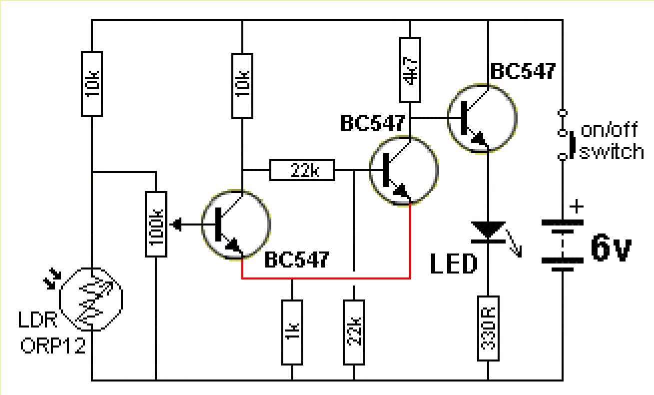


Fig 79. Schmitt Trigger Circuit

Fig 79. This circuit takes a slowly rising or falling voltage and turns it into a fast-acting ON-OFF signal to operate a LED or relay.
This is done via the positive feedback line shown in red. It is called positive feedback because it ADDS to the change to speed it up.
This circuit is fully explained in the: Talking Electronics website CD.

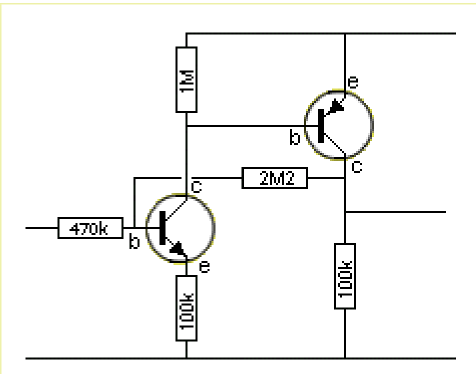


Fig 79aa. A Schmitt Trigger

Fig 79aa is a Schmitt Trigger made from NPN and PNP transistors.
As the voltage on the input rises, the first transistor is turned on slightly and a small voltage is developed across the 100k emitter resistor that reduces the "turn-on" effect slightly. This means the input voltage must rise more. As the input voltage rises more, the second transistor starts to turn on and the collector voltage rises. This voltage is passed to the base of the first transistor to assist the input voltage and because the collector voltage of the output transistor rises considerably, it has a large effect on turning ON the first transistor. They turn each other ON until they are both fully turned ON.

The 2M2 has taken over from the 470k and made the base of the input transistor slightly higher. The input voltage has to drop a small amount before the pair will start to turn off.
The circuit has created a small gap between the low and high input voltage (and between the HIGH and LOW input voltages) where the circuit does not change from one state to the other. This gap is called the **HYSTERESIS GAP**.
The output of the Schmitt Trigger in **Fig 79aa** is classified as "high impedance" (due to the value of the 100k on the output) and this must be connected to a stage with a high input impedance so the voltage on the output of the Schmitt Trigger is not affected.

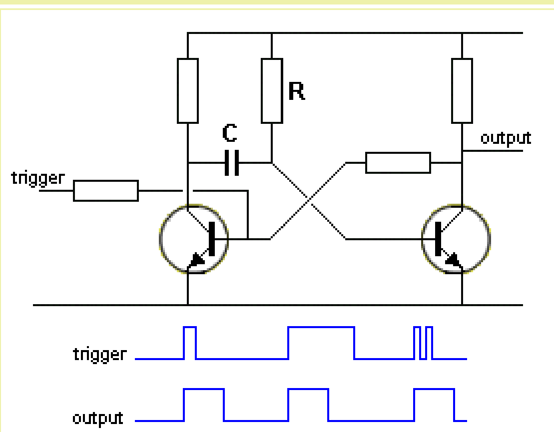


Fig 79ab. The Monostable or "Pulse Extender."

Fig 79ab. Before we leave the MULTIVIBRATOR family, the third type of Multivibrator is the **MONOSTABLE MULTIVIBRATOR**.
It is only stable in **ONE** state. This is called the "rest" state. The other state is "timed" via a capacitor.
The circuit is triggered and it changes to the other stage and a TIMING CAPACITOR **C** charges via a resistor **R** (called a TIMING CIRCUIT) and a multiplication of the two produces a value called the **time constant.** When it is charged, the circuit drops back to the rest state.
While the output is high, input pulses (trigger pulses) have no effect on the circuit. Also, if the input is triggered and kept high longer than the **time constant** of **C** and **R**, the output will NOT stay high for longer than the **time constant**.

This circuit is also called a **PULSE EXTENDER**.

GATES

We have described the transistor as an amplifier and the fact that **POSITIVE FEEDBACK** can turn a transistor **ON** more and more, so it changes from: "**not-turned-ON**" to **"fully-turned-ON"** in a very short period of time. When a transistor is operating in this mode, it is said to be in **DIGITAL MODE.**
We saw the effects of **DIGITAL MODE** in Figs 74, 75, 76, 77 and 78. The advantage of **digital mode** is the transistor dissipates the least heat in either state.
The transistor can be put into a chip (IC - Integrated Circuit) and used in Digital Mode. When this is done, the transistor is put into a circuit called a **GATE. A Gate** is simply a **BUILDING BLOCK** in which the output changes from **LOW** to **HIGH** or **HIGH** to **LOW** very quickly. The simplest **GATES** are called AND, OR, NAND, NOR and NOT. In general a GATE operates on a 5v supply (this applies to gates in the TTL family. They cannot withstand a voltage higher than 5.5v. CMOS gates operate to about 14v-16v and some are up to 20v) and the input has to change from **LOW** to **HIGH** or **HIGH** to **LOW** very quickly and the output will change from **LOW** to **HIGH** or **HIGH** to **LOW** very quickly. You may think the gate is not achieving anything, but most gates have 2 or more inputs and the output is "more powerful" than the input. The introduction of GATES revolutionised the development of the computer and was the beginning of the **DIGITAL AGE.**

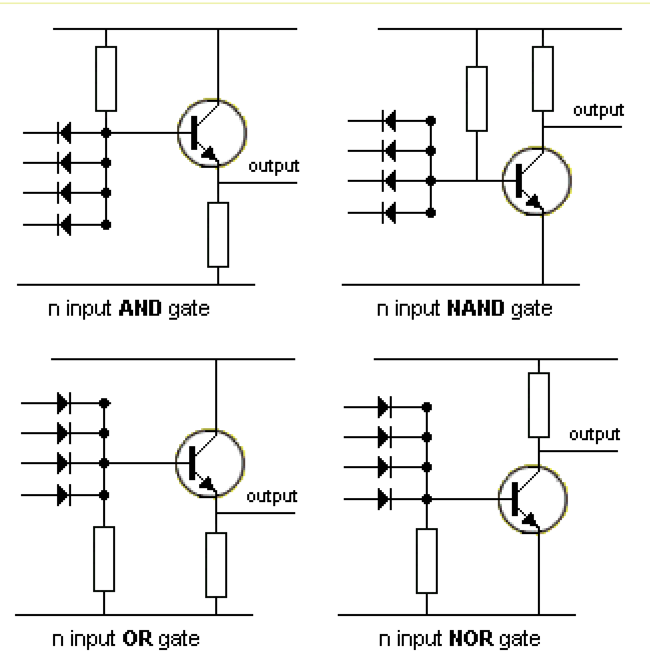
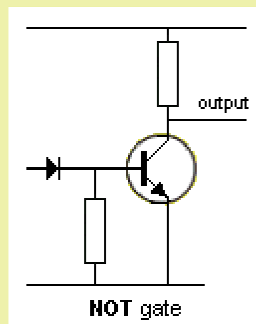


Fig 79ac.

Fig 79ac shows AND, OR, NAND, NOR and NOT gates produced with transistors.



"n" indicates any number of inputs. ("n" is an unspecified number.)

We have shown circuits with the load (such as a speaker or LED) above the transistor or below (it cannot be in both places at the same time). The position of the LOAD introduces two new terms:

SINKING AND SOURCING

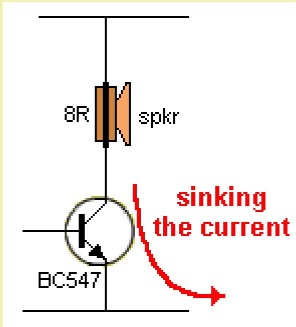


Fig 79b.

Fig 79b. When the speaker (LOAD) is placed above the transistor, the circuit is said to be **SINKING** the current. A BC547 does not have the collector-current to adequately supply an 8R speaker. You really need a BC338.

There is no advantage in one placement over the other. If the load is connected to "chassis" such as a globe in a car, the circuit will need to source the current.

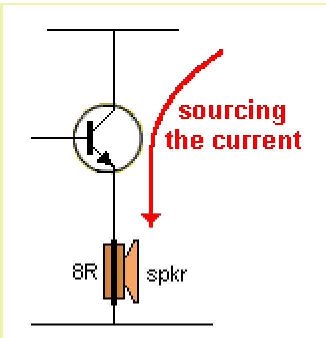


Fig 79c.

Fig 79c. When the speaker (LOAD) is below the transistor, the circuit is said to be **SOURCING** the current.

The only difference between the two circuits is the voltage on the base. Fig 79b will operate with a base-voltage less than 1v, while Fig 79c is an emitter-follower design and will need a voltage on the base from about 1v to full rail voltage.

INTERFACING

Interfacing simply means: "connecting." When a circuit connects a device (such as a microphone), to an amplifier, it is called **INTERFACING**. The characteristics of the microphone are matched to the input requirements of the amplifier. Or a relay may need to be connected to the output of an amplifier (If the amplifier does not have enough current to turn the relay ON).
In most cases, the output of a circuit or a "pick-up" device (sometimes called a TRANSDUCER) does not have enough VOLTAGE or VOLTAGE-SWING or AMPLITUDE to drive the next circuit or device and it needs an amplifier.
That's why we have to add a circuit between.
The circuit we add has a number of names:
When it increases the CURRENT, we call it a **BUFFER**.
When it matches a high impedance to a low impedance or a low impedance to a high impedance, we call it **IMPEDANCE MATCHING**.
Or when we need an increase in voltage, it is called an **AMPLIFIER**.
In ALL "stages" (common-base, common-collector and common-emitter) the current is increased.
Interfacing can be as simple as adding a resistor or capacitor, but this is usually called "connecting" or "coupling".

We have learnt that all devices and circuits have an ability to deliver a "waveform" or "amplitude" or "voltage" and this can be weak or strong according to the amount of current it can deliver.
We have also learnt that this current may be delivered from the load resistor or from the device itself.
It does not matter how the current is delivered; the **size** of the current (the amount of current) is important.

We have also covered the fact that the input to a circuit (or "stage") requires current and when these two are equal, the matching is ideal.
But this rarely happens.

If the input requires **more** current, the voltage (or voltage-swing) from the previous circuit or device will be reduced. If the input requires less current, the voltage-swing will be affected a very small amount. But in **ALL** cases the voltage-swing will be reduced - because you ARE supplying SOME energy to the stage that follows.

Interfacing is not easy.
You have to know the **output voltage** of the device and the **current** it can supply.
The current it can supply is related to its **OUTPUT IMPEDANCE**.
OUTPUT IMPEDANCE basically means its output resistance. A low resistance or LOW IMPEDANCE means it is capable of delivering a HIGH CURRENT. A high-impedance device cannot deliver very much current. A stage with a high output impedance cannot deliver very much current. All these terms are relative. When we say: "cannot deliver much current" the value of current can be less than 1uA or 50mA. It depends on the circuit we are discussing and if you are working with low-current circuits or power circuits.
We have also learnt that the input impedance of a stage can be high or low and the voltage-swing it will accept can be small or large. (for instance, an emitter follower stage will accept a large input voltage).
This gives us a wide range of values (parameters) that may need to be joined together - **INTERFACED**.
In some cases the output voltage of a device or circuit will be HIGH and by connecting a capacitor between the two stages, the output voltage will be "absorbed" in the capacitor and the energy from the output stage will be transferred. The "energy" is a combination of the voltage-swing and the current.
But if the output voltage is very small, we may need to amplify it to deliver a high voltage to a device.

This is the case in the following requirement.
A piezo diaphragm or electret microphone is required to be interfaced to the input of a microcontroller.
The output of these devices is about 10mV and the input of a microcontroller requires about 3.5v (3,500mV).
This involves an amplification (gain, amplification factor) of 10:3500 = 350 and requires two stages of amplification.
The output of a piezo and microphone are classified as high impedance and the input of a microntroller is also high impedance.
This means the two amplifying stages can be low-current stages (also called high-impedance stages) and the load resistors can be high-value (about 22k - 100k).
The following two circuits have been designed for this application:

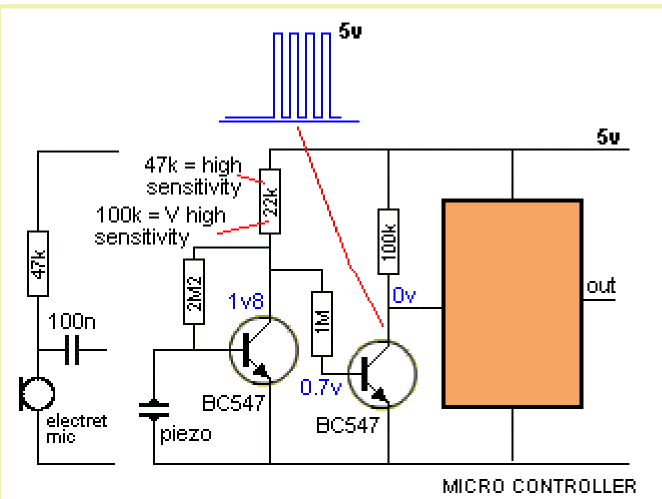


Fig 79d.

Fig 79d. In this circuit the first transistor is self-biased and the 2M2 base bias resistor turns the transistor ON and the voltage on the collector is only about 1.8v.
This means the collector has to drop by only 1.2v for the second transistor to turn off and the 100k will produce 5v on the input to the microcontroller.
If the transistor has a gain of 100, the electret mic or piezo has to produce a 12mV signal to activate the circuit.
When the load resistor is increased to 100k, the collector has about 850mV on it, and it only has to drop 300mV for the signal to enter the microcontroller. This makes the 100k load resistor produce a more-sensitive circuit. When no audio is being detected, the output of the second stage is

0v.

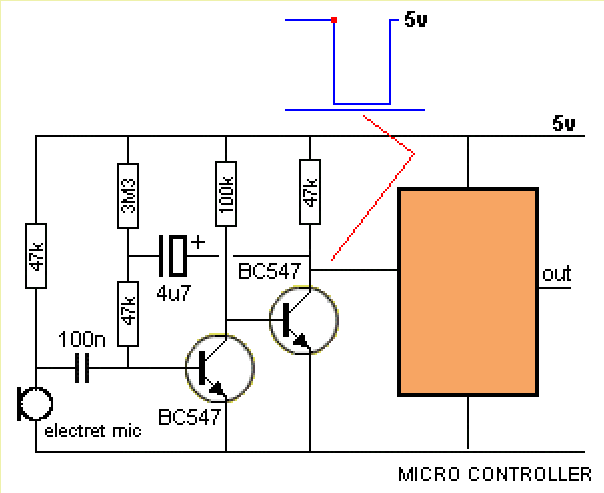


Fig 79e.

Fig 79e. This circuit has been taken from Fig 71acc. It is a bootstrap circuit and produces a very clever "switch."
The circuit sits with the first transistor turned ON and the second turned OFF as can be seen in the first line at the top of the output waveform - up to the red dot. When a signal is picked up by the microphone (this is the red dot on the waveform),
a negative-going signal of about 100mV will turn the transistor off slightly and the second transistor will turn ON. The 4u7 will be "pulled down" and completely take over from the signal from the microphone. It will turn the first transistor off more and the second transistor will be turned ON more. This will continue until both have completely changed states.

They will stay like this until the 4u7 is charged in the opposite direction and the base of the first transistor sees 0.7v. This causes the second transistor to turn off and the 4u7 rises and turns the first transistor ON more. The 4u7 gets slowly discharged and the circuit remains in this state.
The circuit produces a very clean output every time it detects audio.
The duration of the low in the graph can be shortened by reducing the value of the electrolytic.

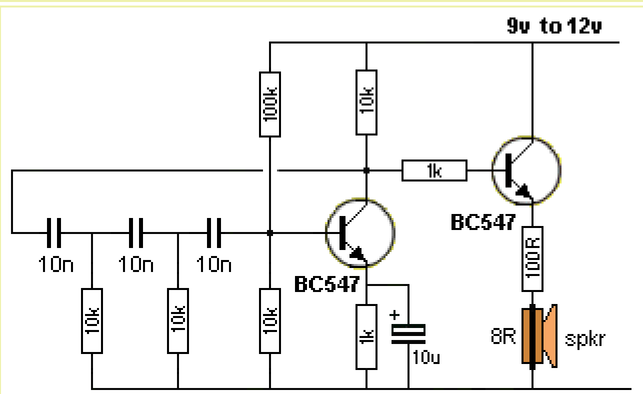


Fig 79f

Fig 79f interfaces a phase-shift oscillator (see **Fig 90**) to a speaker. This is a very difficult thing to do as the phase-shift oscillator has an output that is very close to rail-to-rail and any loading of the output will cause it to stop working.
In an attempt to interface the oscillator to a speaker we have added an emitter follower transistor and a 1k separating resistor, plus a 100R in series with the speaker. This should give a loading of about 20k and the circuit should work. Otherwise the 10k will have to be reduced or the 100R increased.

ANALOG TO DIGITAL

Many of the circuits we have described convert an **ANALOG** signal to a **DIGITAL** signal.
These are called **ANALOG TO DIGITAL CONVERTERS** but we have not given them this specific name because we have been concentrating on other features.
We will now cover the concept of **Analogue to Digital Conversion**.
An ANALOGUE signal rises and falls but doesn't have any defined amplitude or frequency.
This signal cannot be delivered reliably to a circuit that requires a DIGITAL SIGNAL as the amplitude may not be large enough.
A **DIGITAL CIRCUIT** requires a **digital signal** and this type of signal is either a constant HIGH or LOW and the amplitude must be very close to rail voltage or almost 0v. And it must change from one state to the other **very quickly**.

Delivering a high amplitude analogue signal **may** be recognised by a digital circuit when it reaches a peak or goes to 0v, but this is not guaranteed or reliable.
In addition we may want the signal to be a CONSTANT HIGH when the audio is present.
This is what an **ANALOG TO DIGITAL** circuit will do. It will produce a constant HIGH when audio is present and ZERO (LOW) when the audio is not present. Or pulses that are nearly rail voltage and very close the 0v.

Recapping:
To convert an analogue signal to a digital signal we need to deliver ZERO OUTPUT (called a LOW output) when the signal has a small amplitude and a HIGH output when the signal has a high amplitude.
To do this we use a common-emitter stage, as it has a high voltage-gain and this is what we need.

There are many ways to convert an **Analogue signal** to a **Digital signal** but the basic way is to amplify the signal by a large amplification-factor so the resulting waveform will rise to the voltage of the rail (or even higher). It cannot go higher than rail voltage but you will see what we mean in a moment.
This is normally called "over-driving" the signal and if this is done in an audio circuit, the result is distortion. But we are not going to listen to the output, so we take advantage of this feature to produce a DIGITAL OUTPUT.

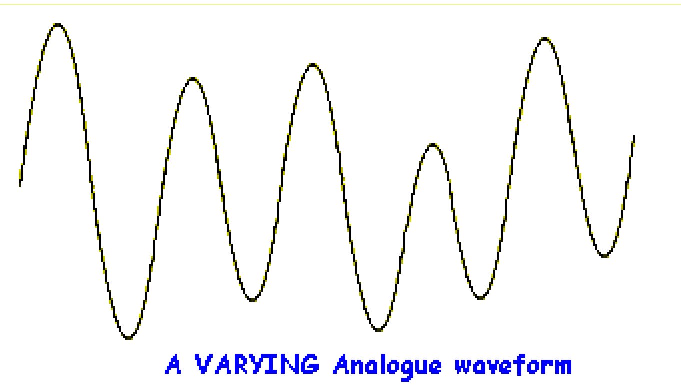


Fig 80a

Fig 80a shows an analogue signal. It is made up of lots of sine-waves and may be as high as 2v or only a few millivolts. Low-level signals are generally expressed in mV, to make them instantly recognisable and easy to talk about. In general this type of signal will be too small to be detected by a Digital Circuit. A Digital Circuit needs a signal greater than about 3,500mV so the waveform appears on the input line as a HIGH, during the peak of its excursion. It should be nearly 5,000mV for reliable detection.

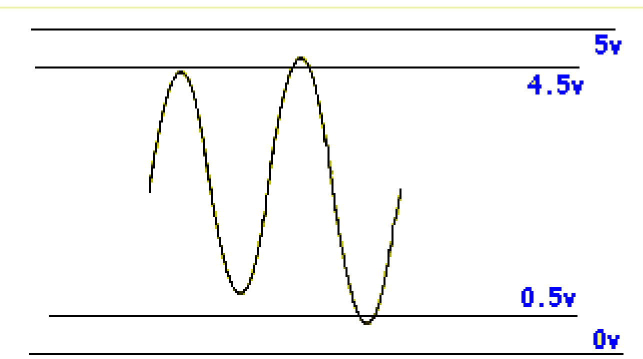


Fig 80b. A Digital Circuit will detect a waveform larger than 4.5v as a HIGH and less than 0.5v as a LOW

Fig 80b. Only the large excursion(s) will be detected by a Digital circuit as the other parts will not rise high enough to be detected. To increase the analogue signal to as much as 5,000mV, an amplifier is needed.

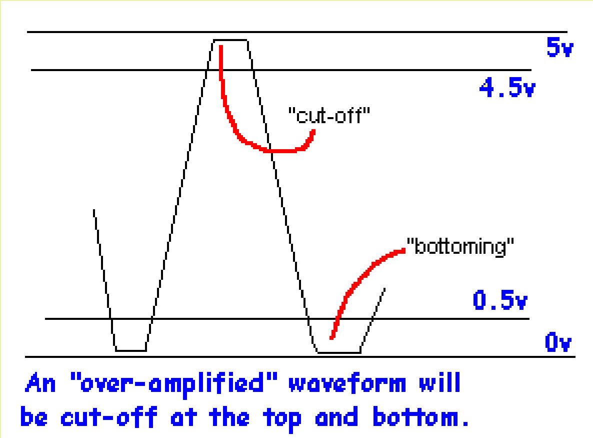


Fig 80c.

The amplifier maybe one or two stages, depending on the amplitude of the original signal. Each stage of an amplifier will increase the size of the signal about 70 times. If you are very lucky, you may get an amplification of 100x (100 times). Thus a 5mV signal with one stage of amplification will produce a 350mV to 500mV signal. This is not sufficient to be detected by a Digital Stage. Another stage will easily produce a full 5,000mV signal.
The second stage only needs to amplify the signal about 10 to 12 times and a higher gain simply drives the waveform into "**bottoming**" and "**cut-off**" as shown in **fig 80c**.

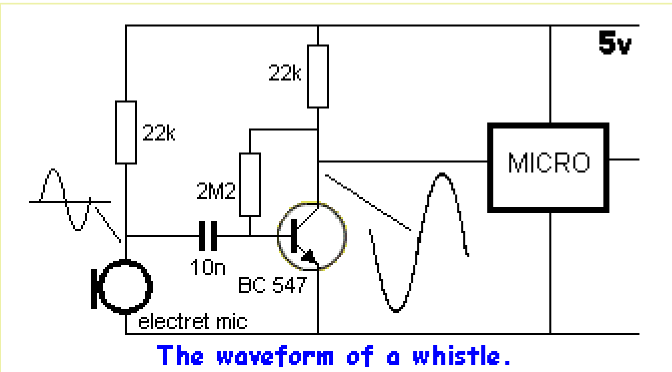
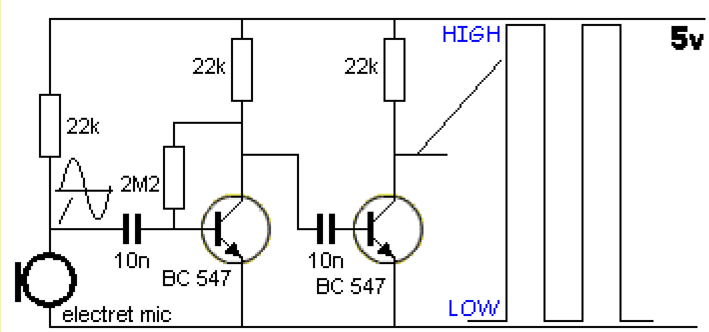


Fig 80d.

This means the waveform will be "clipped" at the top and bottom and converted to a fairly "square-ish" shape.
Suppose you have a waveform that is higher than 5mV (say 30 - 50mV) and want to know if it will trigger a Digital Circuit with a single stage of amplification.
Connect the components as shown in **Fig 80d** and write a program to illuminate a LED when the waveform is detected.

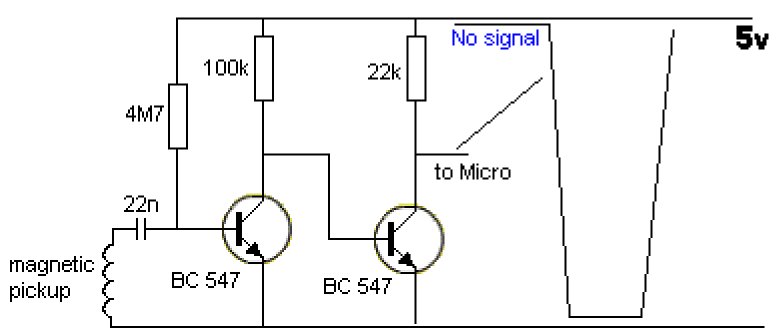
There is only one problem with the circuit in Fig 80d.
At the end of a whistle or speech, the LED may be illuminated or extinguished. It all depends on the last cycle of the waveform. The circuit sits with the output approx mid-rail and the micro does not know if this is a high or low, and takes the reading by the direction of the last cycle.
Some of the inputs of a micro are Schmitt Triggered. This means a HIGH has to be 85% to 100% of rail voltage for it to be seen as a HIGH and between 20% and 0% to be seen as a LOW.
The non-Schmitt Trigger inputs see a LOW as 20% to 0% and a HIGH as above 2v for 5v operation.
If the last cycle went from zero to mid-rail the micro will see the waveform as a low on Schmitt Trigger inputs and a HIGH on the other inputs. This problem can be overcome by adding a second stage that only produces a LOW when audio is detected. It also increases the amplitude of the audio to guarantee triggering of the Digital Circuit. This is shown in **Fig 80e**.



A two-stage amplifier with the second stage only responding to signals, greater than 650mV. The second stage converts analogue signals into digital.

Fig 80e.

The second transistor in **Fig 80e** is called a DIGITAL STAGE. This simply means a biasing resistor is not connected to the base of the second transistor so it turns on fully when a signal greater than 650mV is detected and is turned off at other times. This stage is ideal for a micro or other Digital Stage as only two voltage levels are delivered. Either 0v or rail voltage (5v).The other advantage is it does not take any quiescent (idle) current.
This stage is only suitable if you are sure you have plenty of "over-voltage" to drive the transistor into saturation. By this we mean you must have at least 1v (1,000mV) drive signal so you can be sure the transistor will turn on (saturate).
The fast rise and fall times means you have a "clean" HIGH and LOW.



A two-stage amplifier interfacing a magnetic pick-up to the input of a micro.

Fig 80f.

Fig 80f couples a magnetic pick-up to the amplifying circuit so the biasing of the first transistor can be determined by the value of the base-bias resistor. The coil cannot be connected directly to the transistor as the low impedance (resistance) of the coil will upset the bias on the base.

With this arrangement, the descending part of the input waveform of a few millivolts will turn off the transistor, while the ascending part of the waveform will not have any effect.
A coil of wire of any size will be suitable and to make it an effective collector of magnetic flux, it should have a magnetic core such as ferrite. No other impedance-matching is necessary.

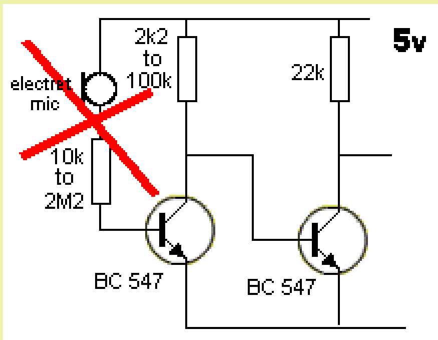
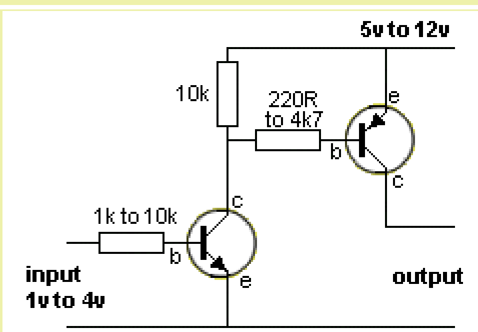


Fig 80g.

Fig 80g shows an electret microphone connected directly to the base of a two-transistor amplifier. This arrangement will work and provides the best transfer of signal from the microphone to the base. But biasing the first transistor is a very difficult thing to do. The electret microphone needs a very small current to operate and the series resistor allows this current to flow.
You will need to build the circuit, select values for the base and collector then whistle into the microphone to see which combination produces the highest gain.
If the resistor is a small value, the base current will be high and the transistor will be turned on fairly hard. This is called BOTTOMING and the collector voltage will be very low.

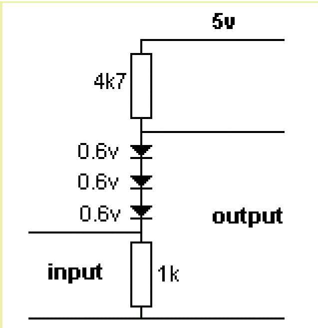
The electret microphone will produce a signal and this will increase and decrease the current into the base. But the reduced current will no turn the transistor off any appreciable amount and the signal will not appear on the collector. If the base resistor is very high, the electret microphone will not produce a very large output signal and again, the waveform on the collector will be very small.
There is no way anyone can predict the best values to use. It depends on the type of microphone, the gain of the transistor and the rail voltage. This is a very messy design and should be avoided. It has been included because it has been seen in circuits on the web.

LEVEL CONVERSION



LEVEL CONVERSION

Suppose the output of a device is 3v and you want to active a device that requires 5v or 12v.
This circuit converts the signal that rises from about 0v to about 4v to a signal that rises from 0v to 5v or 12v.
Note: The output is not inverted, it is in-phase with the input due to two inversions within the circuit.
The resistor values and the type if transistor will depend on the output current required.



LEVEL CONVERSION with Diodes

Level conversion can be done with 3 diodes to change 3.3v to about 5v, but you have to know the current-capability of the 3.3v source and the current requirement of the 5v section.
This arrangement is only suitable for very small current requirements.
The output is allowed to be taken HIGH by the input providing 3.3v and the 3 diodes providing 2.1v. This allows the 4k7 to pull HIGH with a very small current-capability.

OSCILLATORS

There are over 20 different types of oscillators and many more variations. We cannot cover them all - so we will concentrate on the most often-used and explain how they work.

Oscillators consist of one or two transistors. They start-up by one or more components in the circuit producing "noise" or a spike from the "mains" when the circuit is turned on. Some oscillators will not start-up if the supply is increased gradually. When a spike or noise is detected, the rest of the circuit amplifies it. In most cases the noise comes from the circuit being turned ON but it can also come from the noise generated within the junction of a transistor. This noise is random and of little use, but it is fed to components such as coils and capacitors as they have the ability to produce a waveform that rises and falls smoothly and this is amplified to produce the output.
When coils, crystals, capacitors and resistor are combined with transistors, many different effects and waveforms can be created and this all comes under the heading of OSCILLATORS. And the circuits are all amplifiers.
An amplifier can be turned into an oscillator by providing POSITIVE FEEDBACK.
The purpose of providing **NEGATIVE FEEDBACK** is to prevent oscillation.
The purpose of providing **POSITIVE FEEDBACK** is to create oscillation.
Positive feedback is when you take a point that is rising a **large amount** and pass it to a point that is also rising at the same time but only a **small amount**.
In other words, the feedback line must be able to **help** or **assist** the small-signal line. If it does not **assist** the small-signal line, NO oscillation will occur.
Some oscillators have a name - either after their inventor, by the way they are configured or by the shape of the wave. Some have 5 names. **Some have no particular name and are just called Feedback Oscillators (positive feedback).**

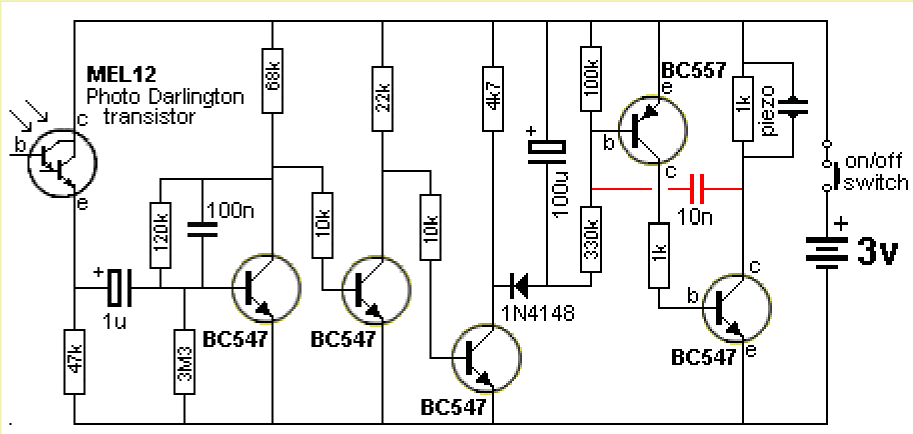


Fig 80. A Feedback Oscillator

Fig 80. The 10n capacitor provides the positive feedback to keep the circuit oscillating.

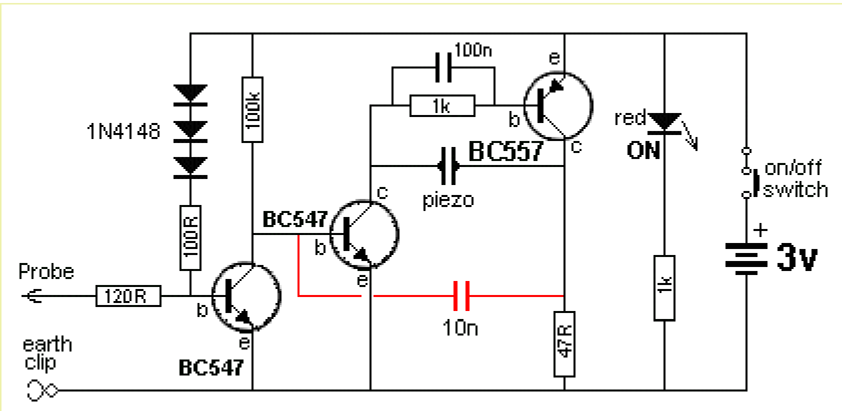


Fig 81. A feedback oscillator

Fig 81. The 10n capacitor provides the positive feedback to keep the circuit oscillating.

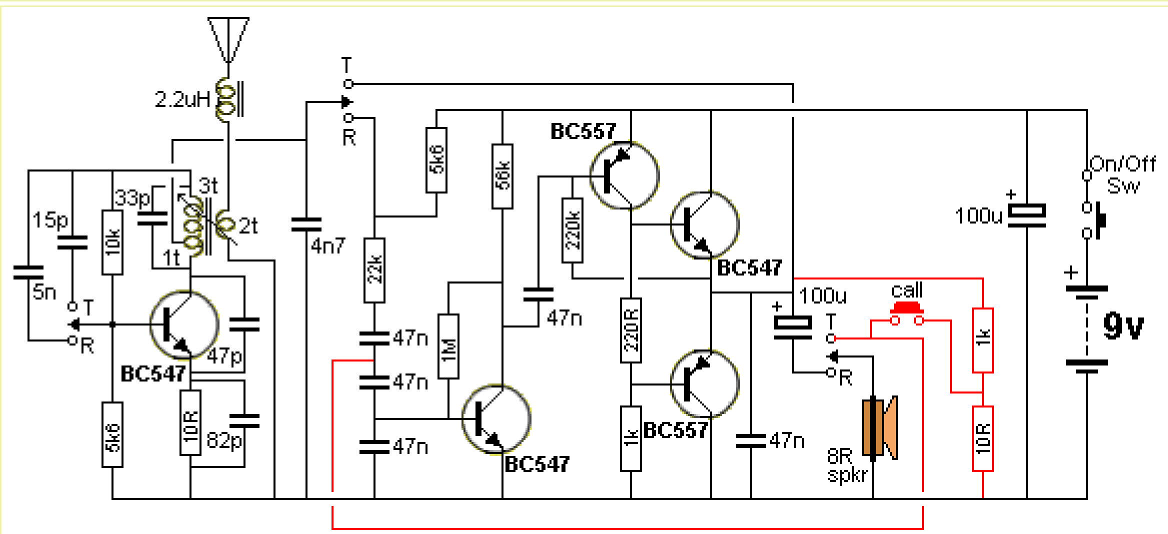


Fig 82. The positive feedback line creates the CALL tone

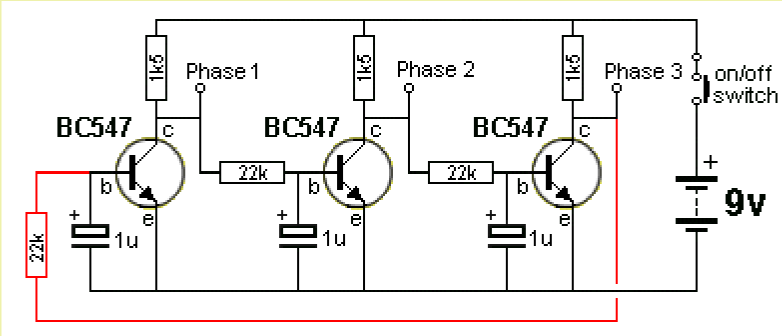


Fig 83.

Fig 83. When the third transistor is turning OFF, the collector voltage is rising and this is passed to the base of the first transistor, to turn it ON. This is how the circuit keeps "cycling" or oscillating.

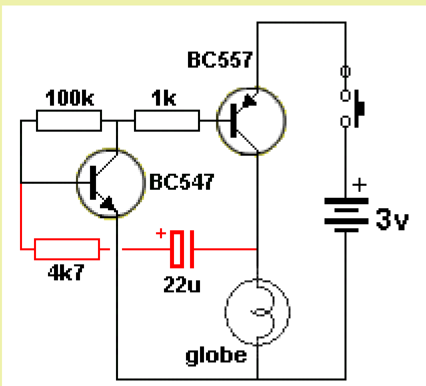


Fig 83a. Globe flashes at 1Hz

Fig 83a. The high-gain amplifier we studied in Fig 66, for example, has negative feedback to prevent oscillation.
By using positive feedback we can turn the high-gain amplifier into an oscillator.
This circuit is simply a high-gain amplifier with both transistors turning ON via the 1k and 100k resistors.
This makes the voltage on the collector of the BC557 rise and the 22u and 4k7 passes this rise to the base of the BC547 to turn both transistors ON more and more until they are fully turned ON.
The 22u charges a little more and this reduces the current into the base of the BC547 to turn it off a little.
This effect is passed to the collector of the BC557 and the two transistors start to turn OFF. When they are fully turned off, the cycle repeats by the transistors being turned on via the 1k and 100k.

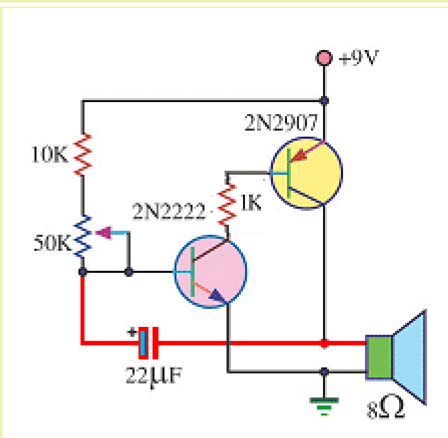


Fig 83aa. Simple Tone Oscillator

The 2-transistor amplifier we studied in Fig 42 can be changed slightly to drive a speaker. The two common-emitter transistors turn on together and the 22u is "lifted" to turn on the NPN transistor harder.
Both transistors turn on until fully saturated and this puts current though the speaker.
The 22u charges a little more and this reduces the current into the base of the NPN transistors, turning it off a slight amount. The PNP is turned off a small amount and they both keep turning off until fully turned off.
The 10k and 50k start to charge the 22u to repeat the cycle. The 22u produces positive feedback. It can be replaced by values from 100n to 22u to change the frequency of the tone.

The two circuits above are examples of **LOW IMPEDANCE** outputs. If the load (the globe or speaker) is increased above about 47 ohms, the circuit will not work. They simply "lock-ON." This is because the capacitor (electrolytic) must be pulled down by the load at a very critical point in the cycle. In addition, the 100k "turn-on" (or 50k and pot) resistor must be a very high value. If it is too low, the circuits will "lock-ON."
The critical point is this: When the circuit is fully turned-ON, the right side of the capacitor is near rail

voltage and it is being charged via the bas-emitter junction of the first transistor. As it becomes fully charged, the current into the base of the first transistor reduces slightly and the transistor turns off slightly. This effect is passed to the second transistor and it turns off slightly too. The right lead of the capacitor drops and this lowers the left lead to turn off the first transistor slightly more. This is the beginning of the "turn-off section" of the cycle.
If the second transistor did not have a very heavy load (low resistance load), the slight turning-off of the two transistors would not lower the capacitor and they would both remain ON.

You can see the importance of FEEDBACK in a circuit. Some circuits will not work without feedback and some will distort. Sometimes the feedback is POSITIVE and sometimes NEGATIVE. The trick to understanding a circuit is to locate the feedback (component or "line") and work out what it is doing.

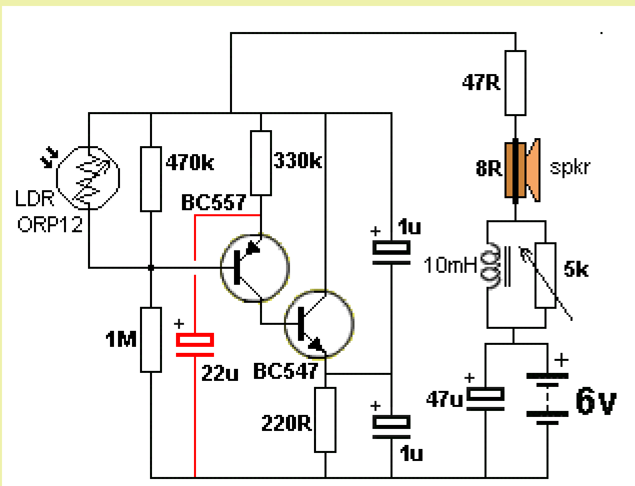


Fig 83b. Positive feedback comes from the 22u electrolytic.
This is a very unusual circuit.
Normally the feedback is obvious.

Fig 83b. Here's an oscillator circuit. We know it must have feedback to operate, but where is the feedback?
In this circuit the 4 electrolytics are equivalent to miniature rechargeable batteries.
When the circuit is turned on, they all get charged to a voltage according to the surrounding components but the 22u is the important component. The base of the BC557 sits at 4v and the emitter must rise to 4.6v for the PNP transistor to turn on. When it does, it turns on the BC547 and this transistor puts a load of 220R across the circuit. This reduces the voltage across the 470k/1M voltage divider and the base if the BC557 sees a lower voltage. During this time the 22u is acting as a miniature supply and maintaining the voltage of 4.6v on the emitter.
The BC547 turns ON more and more and even though the voltage on the 22u drops, the circuit turns ON and this takes more current from the 6v battery and produces a click in the speaker.

THE SQUARE-WAVE OSCILLATOR

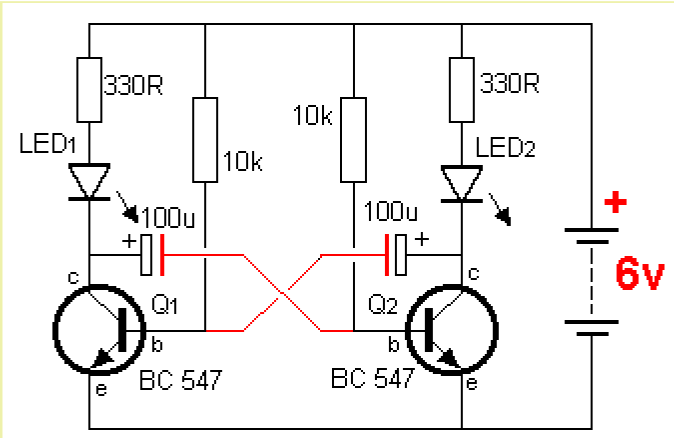


Fig 84.

When two transistors are cross-coupled as shown in **Fig 84**, you can safely assume the circuit will oscillate. The frequency of oscillation will depend on the value of the components but the oscillator is known as a **FREE-RUNNING OSCILLATOR** or **ASTABLE** (ay-stable) **MULTIVIBRATOR** and the output is a square wave. It will have an equal-mark-space ratio if the components are the same value.
This circuit is also called a **FLIP-FLOP**.

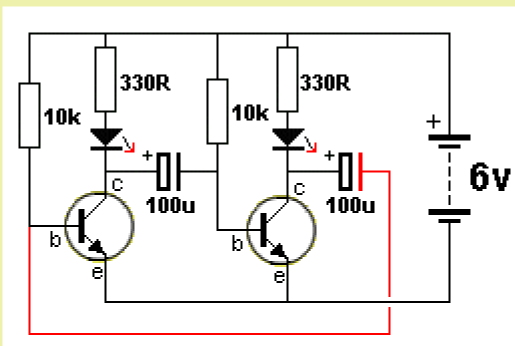


Fig 85.

Fig 85. By rearranging the components in Fig 84, we can draw the circuit as one common-emitter stage driving another common-emitter stage with a 100u providing positive feedback.
The circuit relies on the power being turned on quickly for it to start up. Both transistors will turn ON but one will turn on faster than the other and prevent the other turning on.
The 100u connected to the turned-on transistor will start to charge in the opposite direction and the second transistor will start to turn ON. This will pull the 100u lower and the first transistor will start to turn OFF. This will continue until both transistors have changed states.

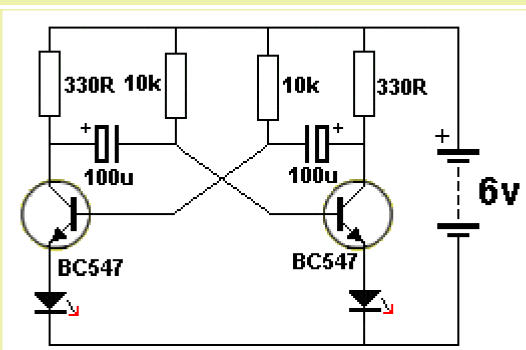


Fig 86.

Fig 86. Here is the **ASTABLE MULTIVIBRATOR** with the LEDs in the emitters instead of collectors (as is normal). The frequency of oscillation is approximately 1 second. The 330 ohm resistors set the LED current to 12mA for a 6v supply.

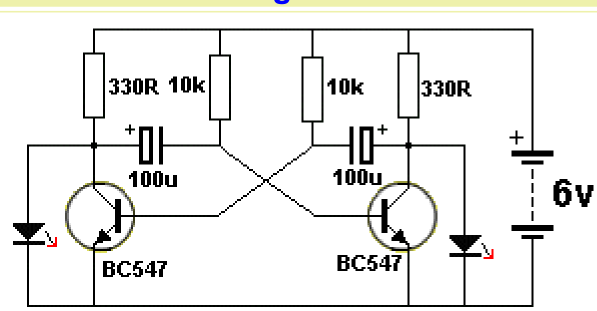


Fig 86a. The LEDs can also be connected as shown in this circuit. However the circuit takes more current than the previous designs. In the previous designs, one side of the circuit is taking current and illuminating the LED while the other side is turned OFF ("cut-off").
In Fig 86a, the "off" transistor is illuminating a LED while the "on" transistor is drawing current though a 330R resistor. Both sides are drawing current! This is a POOR DESIGN.

Fig 86a.	

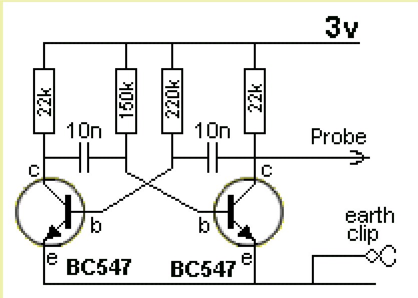


Fig 87.

Fig 87. The **ASTABLE** ("ay" - meaning not-stable) **MULTIVIBRATOR** circuit is rich in harmonics and is ideal for testing amplifier circuits. To find a fault in an amplifier, connect the earth clip to the 0v rail and move through each stage, starting at the speaker. An increase in volume should be heard at each preceding stage. This Injector will also go through the IF stages of radios and FM sound sections in TV's.

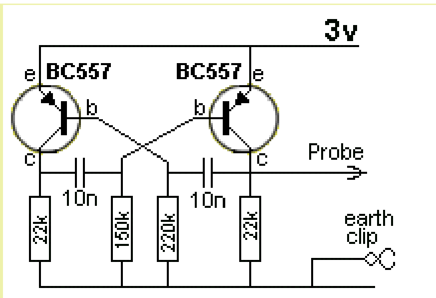


Fig 88.

Fig 88. The astable multivibrator can be made with PNP transistors.

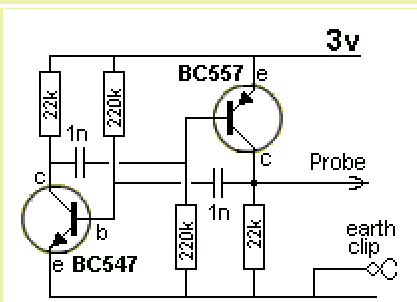


Fig 89.

Fig 89. A circuit can be made with one NPN and one PNP transistor. It ceases to be a FLIP FLOP or Multivibrator as both transistor turn on at the same time and the circuit becomes a **Relaxation Oscillator**.

THE SINE-WAVE OSCILLATOR - also called the PHASE-SHIFT OSCILLATOR

A Sine-wave Oscillator can be made with a single transistor.

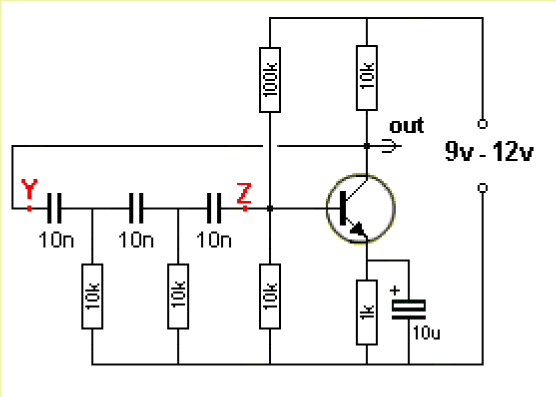


Fig 90. The Sinewave Oscillator

Fig 90. This circuit produces a sinewave very nearly equal to rail voltage.
The important feature is the need for the emitter resistor and 10u bypass electrolytic. It is a most-important feature of the circuit. It provides reliable start-up and guaranteed operation. For 6v operation, the 100k is reduced to 47k.
The three 10n capacitors and two 10k resistors (actually 3) determine the frequency of operation (700Hz).
The 100k and 10k base-bias resistors can be replaced with 2M2 between base and collector.
This type of circuit can be designed to operate from about 10Hz to about 200kHz.

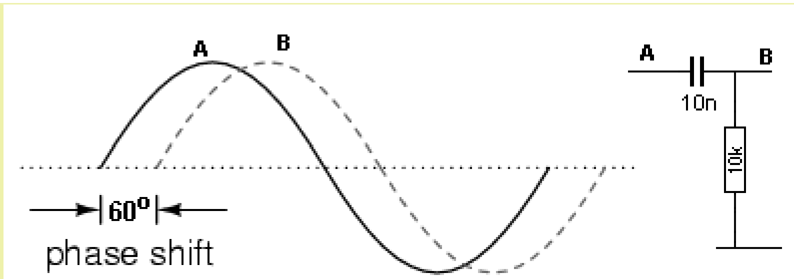


Fig 91.

Fig 91. The phase-shift oscillator has 3 "sections" made up of a 10n capacitor and 10k resistor. This "section" is shown above and each "section" produces a delay or "phase-shift" of about 60° but the total must be 180°. The base and collector of a common-emitter stage are 180° out-of-phase, so the signal entering the base is 360° (IN-PHASE with the output). This creates POSITIVE FEEDBACK.
This concept is very hard to understand so we need to explain it in simple terms.
Points Y and Z are the ends of a long piece of rope and the three resistors are weights tied to the rope.
You shake the rope up and down at Y and Z moves up and down at a later time in the cycle. You know this because you can make a wave travel down a rope. Exactly the same thing happens with a signal that enters at Y. It takes time for the peak to reach Z.
Now consider the circuit at switch-on. The caps are uncharged and the 10k collector resistor pulls the three capacitors high. Taking into account the voltage-dividing effect of the three lower 10k resistors, the collector is possibly at about 2v. The three 10k resistors start to charge the three 10n caps and the voltage on the base falls. This makes the collector voltage rise. This continues until the collector cannot rise any further and the capacitors continue to charge and the voltage on the base drops. The 100k base resistor takes over and starts to discharge the 3rd capacitor and turn the circuit on. The collector voltage drops and the energy in the three capacitors get passed into the base to fully turn the transistor ON.
This all happens in a "sliding motion" that produces a sweeping output called a SINEWAVE. It is a very "delicate" oscillator and any change to the LOAD (10k) may stop its oscillation.

How to read the Graph: Get a ruler and hold it "up and down" on the page (or on the screen) so you view the right-hand edge of the ruler and can only see the word "phase" and "60° " Now slide the ruler to the right and you will see the graph "A" gradually rising. Keep moving the ruler to the right and you will see graph "B" gradually rising.
This is how you "interpret" the graph and see how graph "B" lags (is behind) graph "A." If you don't read the graph correctly, it looks like graph "B" is in front of graph "A" - but this is not the case.

THE BLOCKING OSCILLATOR

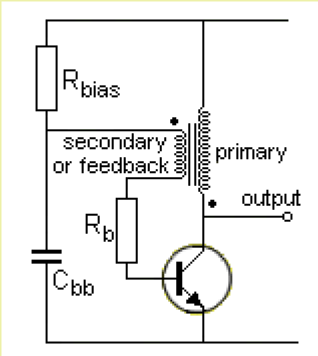


Fig 92.

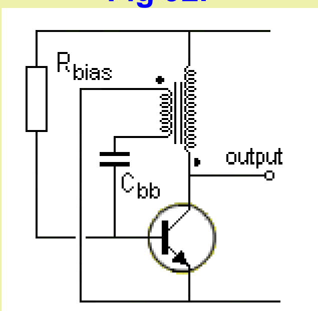


Fig 92a.

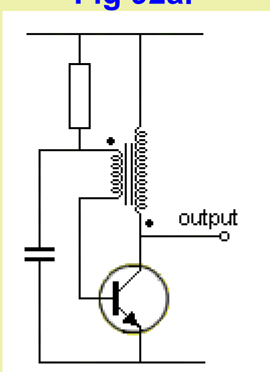


Fig 92b.

Fig 92. The BLOCKING OSCILLATOR circuit uses a transformer to produce POSITIVE FEEDBACK to the base.
The circuit starts by Rbias charging Cbb to deliver voltage to the base of the transistor via Rb (and also a small current). The transistor turns on and produces expanding magnetic flux in the primary of the transformer. This flux cuts the turns of the secondary (or feedback) winding and increases the base voltage and CURRENT. The voltage out of the top of the secondary winding is prevented from "disappearing" by Cbb.
The transistor keeps turning ON until it cannot turn on any more. At this point, the current through the primary is a maximum but it is not expanding flux and its effect is not passed to the secondary winding. The base-current reduces enormously to the very small Rbias current and the transistor turns off abruptly (it takes a high base current to maintain a high collector current and the base current is very small). The heavy current through the primary is producing a very strong flux and it collapses, producing a voltage in both windings of opposite polarity and very high amplitude.

Fig 92a shows the base being "capacitor injected." This saves one capacitor and can produce a higher output. All the values and the transformer needs adjusting for the performance required. The start of each winding is shown with a dot. This assumes the windings are wound in the same direction.

Figs 92b,c shows alternative ways to produce a blocking oscillator. The difficulty with producing a Blocking Oscillator is getting a suitable transformer.

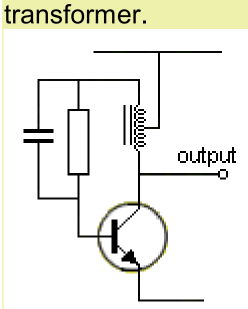


Fig 92c

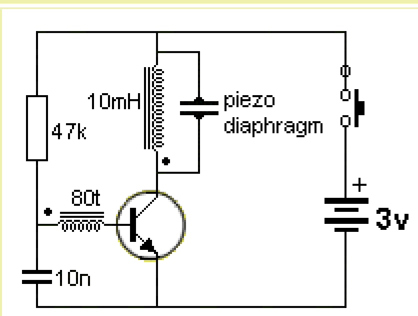


Fig 93.

Fig 93. A simple **BLOCKING OSCILLATOR** circuit can be made with a 10mH inductor and 80 turns of very fine wire wound on top.
The piezo diaphragm reacts to the very high "FLYBACK VOLTAGE" produced by the primary when the transistor turns off. This type of circuit is often used to produce very high voltages.

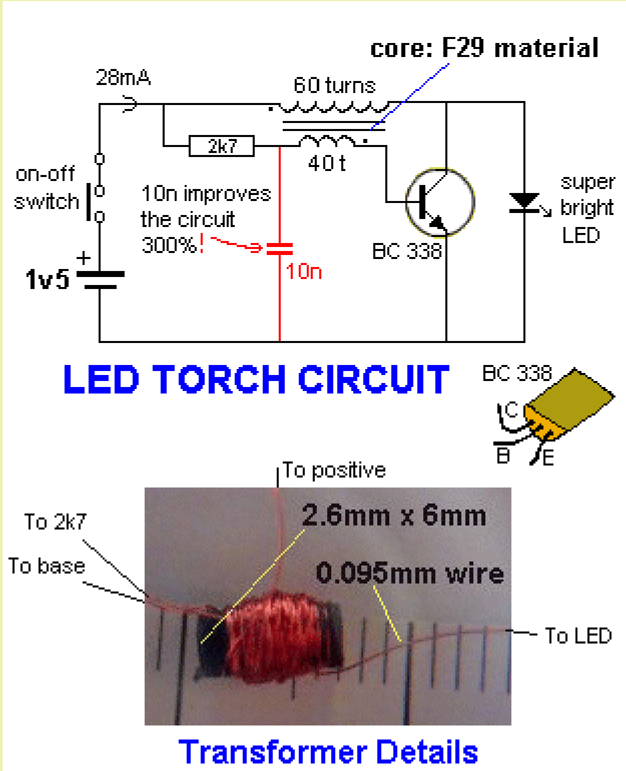


Fig 94.

Fig 94. This LED Torch circuit uses the "flyback" voltage of a BLOCKING OSCILLATOR to illuminate a 3.6v super-bright LED from a 1.5v supply.
Note: the 10n capacitor prevents the energy from the feedback winding being lost. All the energy from the feedback goes into the base of the transistor to turn it on hard.

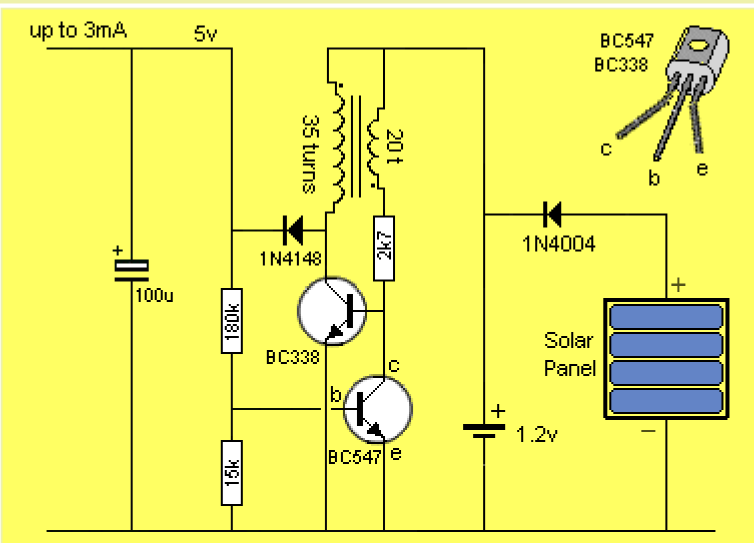


Fig 95.

Fig 95 shows a Blocking Oscillator producing a regulated 5v from a 1.2v supply.

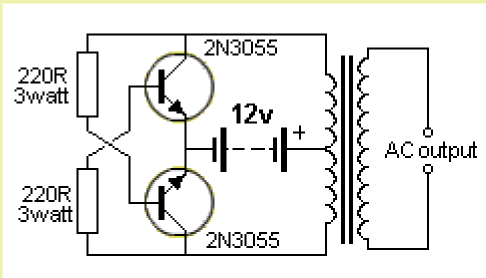


Fig 96. 2-transistors in PUSH-PULL - as a Blocking Oscillator circuit

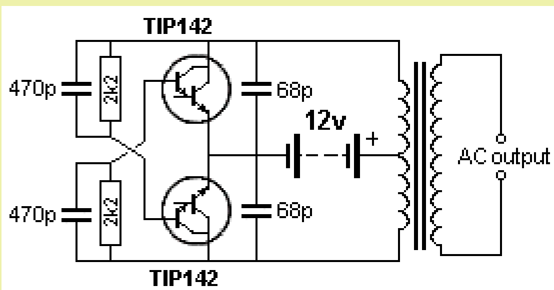


Fig 96a.

Fig 96. A simple extension of the Blocking Oscillator in Fig 92c above, is shown in this diagram. It consists of two **BLOCKING OSCILLATOR** transistors that are turning each other off. The circuit starts by one transistor being slightly faster than the other. It turns ON and produces magnetic flux that cuts the turns of the other half of the primary winding to increase the voltage from the battery and at the same time it reduces the voltage to the base of the other transistor - because the transistor allows only a very small voltage to appear across the collector-emitter terminals when it is turning ON. It keeps turning on until it is fully ON.

At this point the flux is no longer expanding and the generated voltage in the winding that supplies the base voltage (and current) ceases. This turns it off a small amount and the magnetic flux starts to collapse and produce voltages in the opposite direction. The voltage (and current) to the base is less than before and this turns the transistor off more. The voltage to the base of the other transistor starts to rise and that transistor takes over. The two transistors operate in PUSH-PULL mode.

To reduce the wasted power in the 220R resistors, Fig 96a uses Darlington transistors and 2k2 0.5watt resistors. The circuit is used to drive a CFL lamp from a 12v battery.

The difficulty with producing a Blocking Oscillator is getting a suitable transformer. A similar "flyback voltage" can be obtained from an inductor. This will need an oscillator made up of two transistors to drive the inductor.

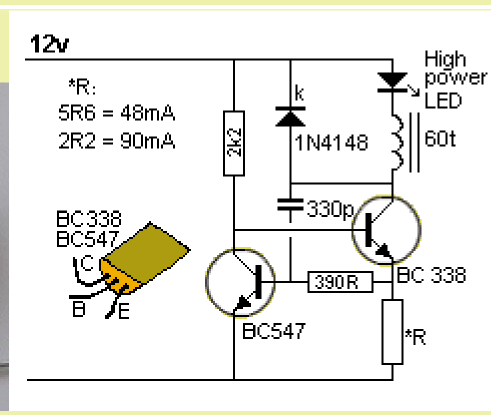


Fig 97.

Fig 97. This circuit is a "Buck Converter" meaning the supply is greater than the voltage of the LED. It will drive one high-power white LED from a 12v supply and is capable of delivering 48mA when R = 5R6 or 90mA when R = 2R2. The LED is much brighter when using this circuit, compared with a series resistor delivering the same current.

But changing R from 5R6 to 2R2 does not double the brightness. It only increases it a small amount.

The inductor consists of 60 turns of 0.25mm wire, on a 15mm length of ferrite rod, 10mm diameter.

Frequency of operation: approx 1MHz. This circuit draws the maximum current for a BC 338.

When the circuit is turned on the 330p gets charged. This turns on the BC547 and keeps the BC338

off. When the 330p is charged the BC547 is not turned on as much and the 2k2 can start to turn on the BC338. It pushes the charge on the 330p into the base of the BC547 to keep it off. The 330p gets discharged by the 330R and the voltage across the *R resistor turns on the BC547 to turn off the BC338. The 1N4148 absorbs the high-voltage flyback pulse. The circuit is only active for a very short period of time and off for a longer period of time. This delivers a small amount of energy to the high powered LED and allows the LED to be connected to a 12v supply (via the circuitry).

THE FLYBACK OSCILLATOR

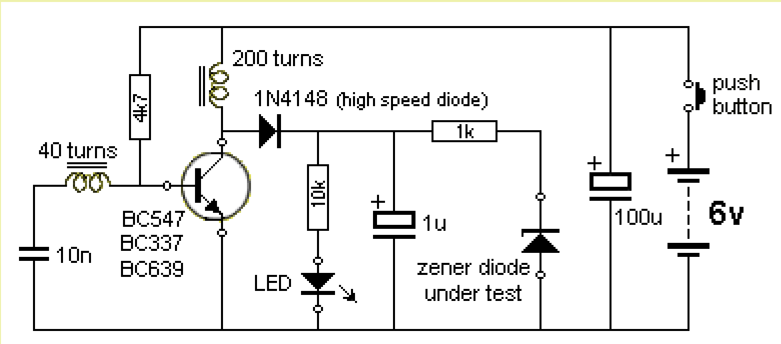


Fig 97a

A flyback oscillator is any oscillator where the transistor turns off quickly and abruptly during part of the cycle and allows the energy (the flux) in an inductor to collapse suddenly to produce a high voltage IN THE OPPOSITE DIRECTION. The circuit in **Fig 97a** consists of a transformer with a feedback winding of 40 turns. It can be constructed as a piece of test equipment to test transistors, zeners and LEDs.

THE BOOST CIRCUIT or BOOST CONVERTER

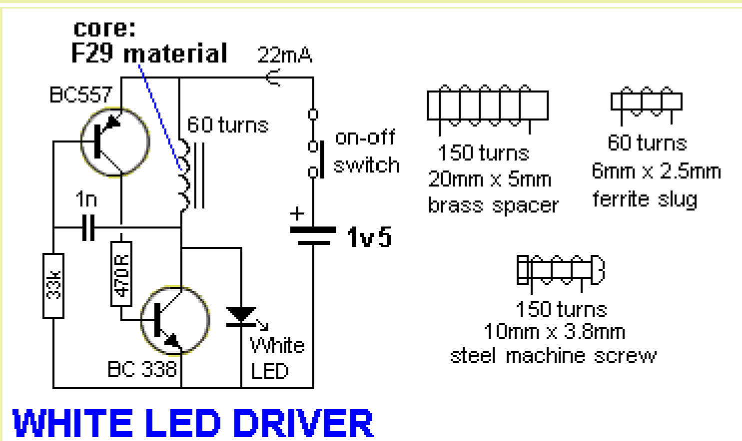


Fig 97aa

Any circuit that converts a low voltage to a higher voltage is classified as a **BOOST CONVERTER** or **BOOST CIRCUIT**.
Fig 97aa will drive a super-bright white LED from a 1.5v cell.
The 60 turn inductor is wound on a small ferrite slug 2.6mm dia and 6mm long with 0.25mm wire.
The main difference between this circuit and the two circuits above is the use of a single winding and the feedback to produce oscillation comes from a 1n capacitor driving a high gain amplifier made up of two transistors.
The feedback is actually positive feedback via the 1n and this turns on the two transistors more and more until finally they are fully turned on and no more feedback signal is passed though the 1n. At this point they start to turn off and the signal through the 1n turns them off more and more until they are fully turned off. The 33k turns on the BC557 to start the cycle again.

THE BUCK CONVERTER

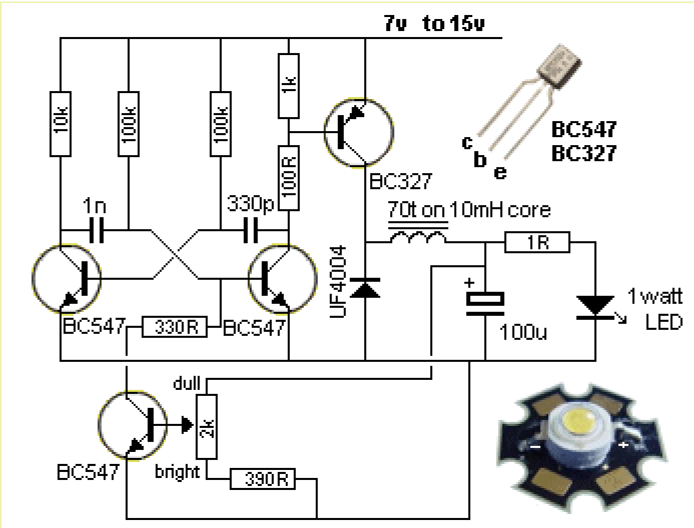


Fig 97b

Any circuit that converts a high voltage to a lower voltage is classified as a **BUCK CONVERTER**.
Fig 97b will drive a 1watt white LED from a 12v supply and is capable of delivering 300mA. The driver transistor is BD 327 and the inductor is 70 turns of 0.25mm wire wound on the core of a 10mH inductor. The voltage across the LED is approx 3.3v - 3.5v The 1R is used to measure the mV across it. 300mV equals 300mA LED current.
The diode MUST be high speed. A non-high-speed diode increases current 50mA.
This circuit is a very good design as it does not put peaks of current though the LED.

MORE OSCILLATORS

The Armstrong, Clapp, Colpitts, Hartley, Wien Bridge and even unknown oscillators like the one below all use capacitors, resistors and coils to create a circuit called a RESONANT CIRCUIT and these two components produce a sinewave when they receive a pulse of energy.

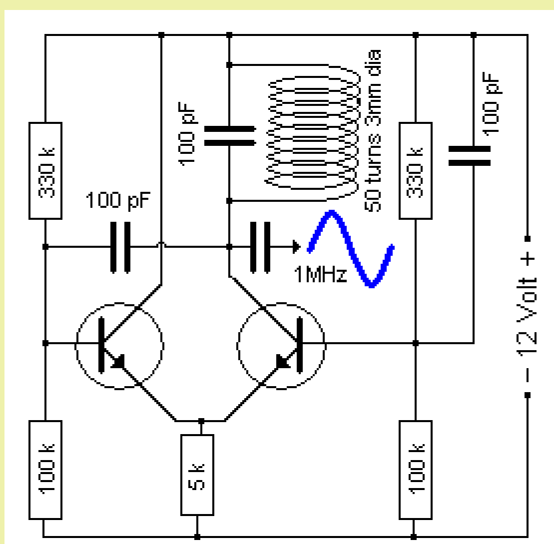


Fig 98.

We are going to lump all these oscillators together as they are variations on a similar design. There are two common oscillators that can be recognised by the layout of the circuit. The Colpitts oscillator has 2 capacitors across the coil with the signal taken from the join or it may have a tuned circuit with

the signal taken from the active end. The Hartley Oscillator has a tapped coil and these are difficult to obtain.

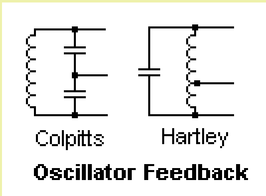


Fig 99.

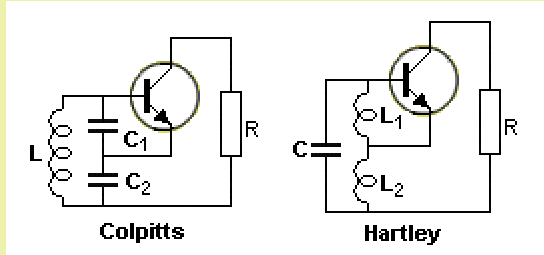


Fig 99a

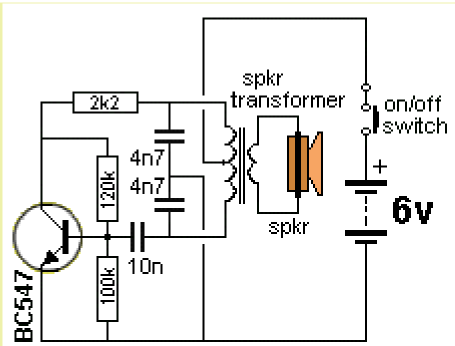


Fig 100. Colpitts Oscillator

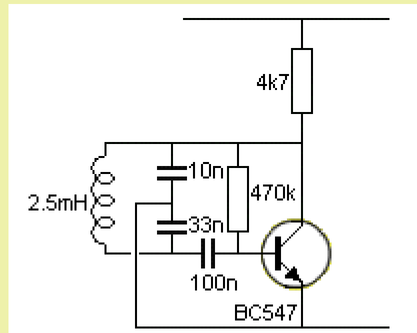


Fig 101. Colpitts Oscillator

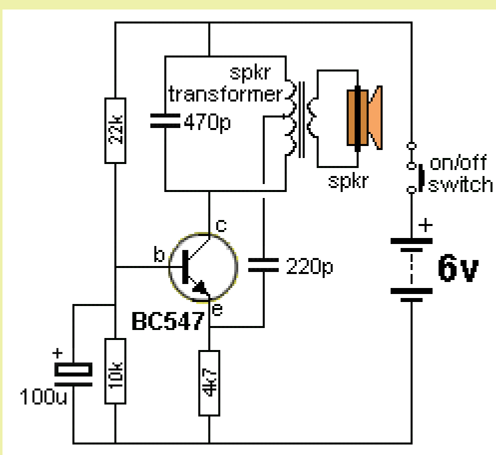


Fig 102. Hartley Oscillator

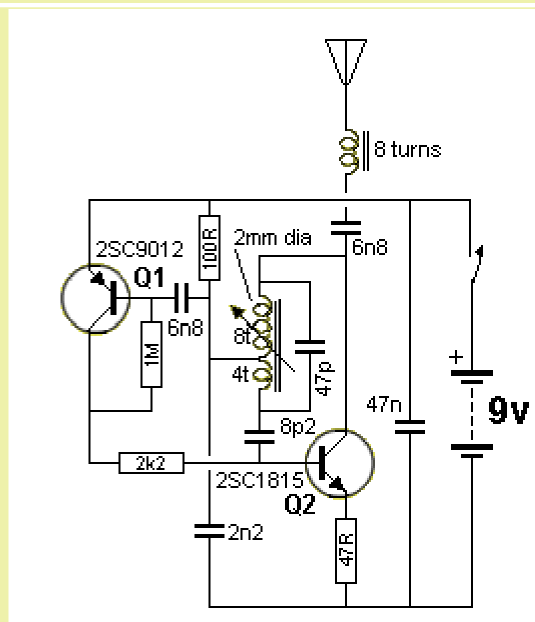


Fig 103. Hartley Oscillator

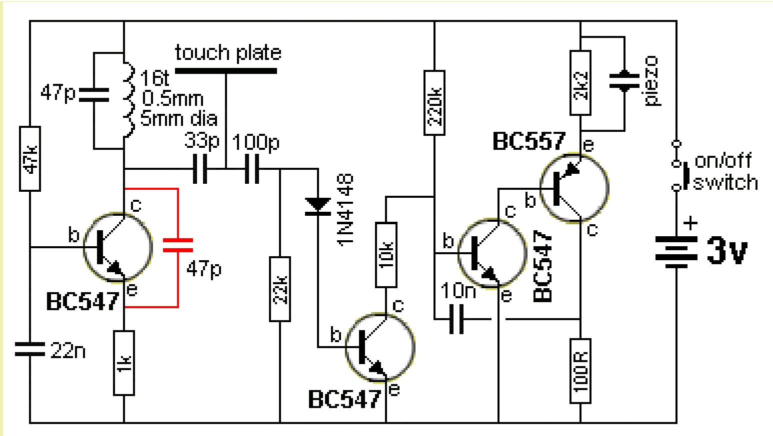


Fig 103a. Door Knob Alarm

DOOR-KNOB ALARM

This circuit can be used to detect when someone touches the handle of a door. A loop of bare wire is connected to the point "touch plate" and the project is hung on the door-knob. Anyone touching the metal door-knob will kill the pulses going to the second transistor and it will turn off. This will activate the "high-gain" amplifier/oscillator.
The circuit will also work as a "Touch Plate" as it does not rely on mains hum, as many other circuits do.
The first transistor is a **Colpitts Oscillator** and the feedback is via the 47p. Explaining the operation of this oscillator could take a page of discussion. We are only going to explain one amazing feature - how the oscillator creates the second half of its cycle. We know how the stage turns on (via the base-bias resistor) - but how does it turn OFF to create the other half of the waveform. Here's how:
We know that when a transistor turns ON, the collector voltage falls and the emitter voltage rises. Simply joining these two points with a resistor or capacitor will not produce feedback as one is falling and the other is rising. We need to join two points that are rising AT THE SAME TIME.
The secret comes from the inductor. The 16 turns of wire produces a voltage in the opposite direction when the transistor is turned off.
In the first diagram of fig 103b we see the transistor turned ON and current flows through the coil. The voltage at the bottom of the coil will be slightly lower than the supply voltage. When the transistor is turned off, it is effectively out of the circuit and the current flowing through the coil produces magnetic flux that will collapse very quickly and produce a voltage across the ends of the coil that will be OPPOSITE to the applied voltage. This means the voltage at the bottom of the coil will be HIGHER than rail voltage and we can think of the coil rising above the power rail and producing a voltage 2, 5, 10 or even 100 times higher than the power-rail voltage.
This is the amazing fact about a coil (inductor) and is the secret behind the operation of this circuit.

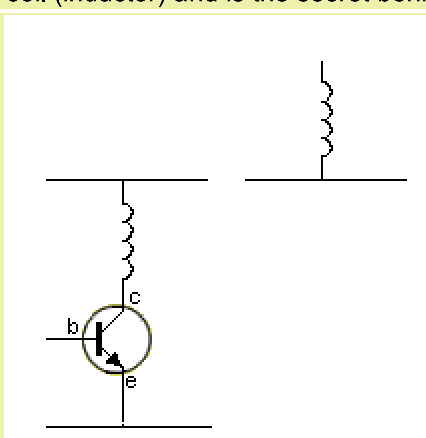


Fig 103b.

In circuit 103b, this high voltage is produced at some point in the cycle and it pulls the emitter UP a small amount via the 47p and this turns the transistor OFF. We are not going into what part of the cycle produces the high voltage via the inductor but it DOES. That's how the circuit produces the second part of its cycle. The inductor produces a high voltage that starts to turn off the transistor and this allows the inductor to produce a higher voltage and the transistor is turned off even more. During this time the 47p feedback capacitor is charging and RISING.
Most oscillators are described on the web and you can decide which type you need for your particular application.

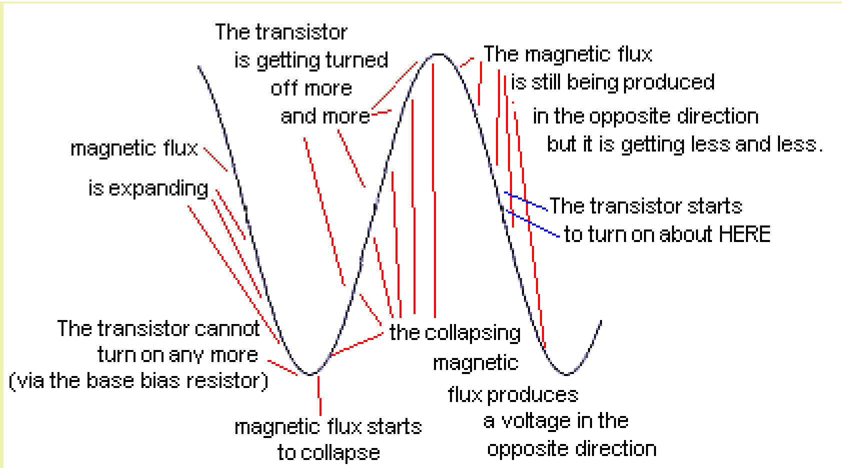


Fig 103c.

THE FEEDBACK CAPACITOR

The author was asked how to work out the value of the feedback capacitor in an oscillator.
There are many different oscillator circuits and in some oscillators, the feedback capacitor sets the frequency of operation for the circuit.
Rather than trying to work out the value mathematically, it is best to refer to a circuit that is already operational and copy the value. You will be able to increase or decrease the value 30% to get your required frequency but any value less than 50% may not produce enough feedback to keep the circuit oscillating.
You may need to increase the base-bias on the transistor to give the transistor more gain.
In some oscillator circuits, the feedback capacitor does not set the frequency. It is determined by a capacitor and coil in a TANK CIRCUIT.
The same suggestion applies. Refer to a circuit that already operates at the frequency you require and use the same value capacitor.
You can halve the value and double the value and use a number of different transistors to make sure the circuit still operates.
This proves the value you have selected is not at the extreme limit of operation.

OSCILLATOR SUMMARY

Look for a TUNED CIRCUIT and feedback line. It will be an oscillator.
Most have a high-impedance output and must be connected to a circuit that will not "load" them (and reduce the amplitude of the output) or prevent them oscillating. But some oscillators have a very low output impedance and can drive a low-impedance device. You have to be aware of these features.

IMPEDANCE MATCHING

Every electronic component has a value of resistance. You can measure this value with a multimeter. But sometimes the value changes according to the light it receives, the frequency it is operating-at, or the voltage it is connected-to, or the sound it receives, or its temperature or many other influences. Sometimes the output from a circuit might be 2v, but if you put a low-impedance device such as a speaker on the output, it "kills" the sound.
Or you may have a nearly flat 9v battery. It measures 5v with a multimeter but when you connect a 3v motor, it does not work.
These are both examples of poor IMPEDANCE MATCHING - yes, the battery has a HIGH Impedance and that's why it cannot deliver the current required by the motor.

What is **IMPEDANCE MATCHING**?

Impedance Matching is is connecting two items together so: "THEY WORK."

Some devices PRODUCE or DELIVER a signal or a voltage or a current.
Some devices ACCEPT a signal or voltage or current.
We need to connect these types of devices together.

Let's start with those that DELIVER:
An amplifier may be able to produce an output of 2v, but when a low-impedance device (low resistance device) such as a speaker is connected, it cannot deliver the CURRENT needed to drive the speaker. The same with a flat 9v battery. It cannot deliver the CURRENT needed to drive a 3v motor.
You cannot "test" or measure the output capability of a device. You must connect it to the input of the project you are designing and measure the waveform or voltage being delivered (or transferred).
If the voltage or waveform is considerably less than when it is not connected, you have decide if the attenuation (reduction) is acceptable. The ideal situation is NO attenuation - but in nearly all cases you will get some attenuation.

There are no "rules to follow" and every case is different. However when the output of a device is NOT reduced when it is connected to a circuit, the two items are said to be IMPEDANCE MATCHED.

There are three ways to "Match Impedances:"
1. via a resistor. This is generally a poor way to match impedances and is very inefficient. But it may be the only way to connect two devices.
2. via a capacitor. This can be a very good way to match impedances.
3. via a transformer. Generally the most efficient way to match impedances but requires a lot of calculation and expense in getting the transformer designed and manufactured.

Impedance Matching can also be referred to as "MATCHING" and the simplest example is connecting a 6v globe to a 12v battery. This is called "Resistance Matching" or "Current Matching" or "Voltage Matching" because the resistance, voltage and current are known quantities.
[To connect a 6v globe to a 12v battery you can use a resistor or put two 6v globes in series. Using a resistor will be very difficult because a globe requires about 6 times normal current to allow it to start illuminating and then it takes the "rated current."]
But when when a device produces a signal; the voltage, resistance and current changes during the production of the signal and because these values are not constant, we use the term **IMPEDANCE MATCHING**.
Impedance really means "resistance that changes during the production of the waveform."

Impedance matching can be worked out mathematically, but you need to know all the parameters of the device and the circuit you are connecting together. This is rarely possible to obtain.
Rather than calculate the result, it is much easier and more-accurate to connect the two items and view the result on a CRO (Cathode ray Oscilloscope). But if you cannot do this, simply connect them and listen or view the output from a speaker, relay or LED etc.

We have already studied "Impedance Matching" in the circuits above, but did not identify the concept. We will now go over some of the circuits and show where impedance matching took place:

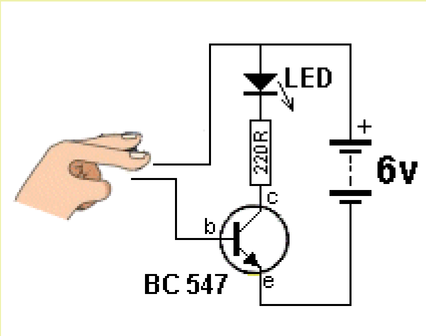


Fig 6

In **Fig 6**, the transistor matches the HIGH IMPEDANCE of your finger to the LOW IMPEDANCE needed to turn on the LED. The transistor converts the 50k resistance of your finger to less than 0.5k (due to the gain or amplification of the transistor of about 100 -200).
You can also say it matches the HIGH RESISTANCE of your finger to the LOW RESISTANCE needed to turn on the LED.

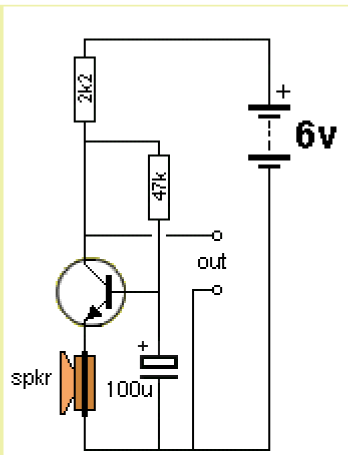


Fig 64

In **Fig 64**, the transistor matches the LOW IMPEDANCE of the speaker to produce a HIGH IMPEDANCE output on the "out" terminals, suitable for delivering to the input of an amplifier. The transistor converts the 8 ohms of the speaker to more than 800 ohms (possibly 1600 ohms) due to the gain or amplification of the transistor (about 100-200) and at the same time the 0.5mV produced by the speaker is amplified to about 40mV to 80mV.

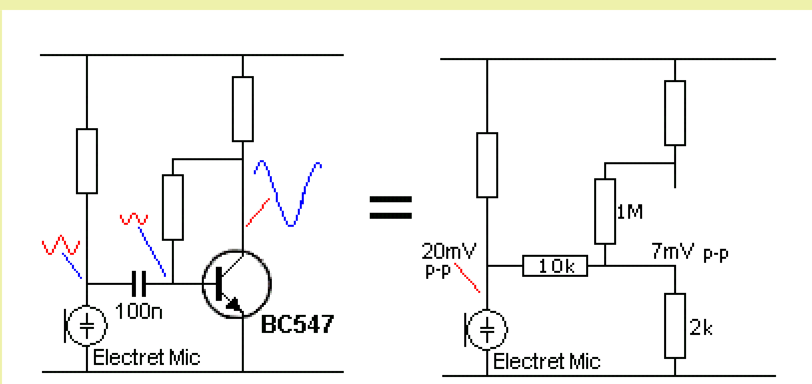


Fig 71f

The 100n capacitor in **Fig 71f** matches the impedance of the electret microphone to the input impedance of the transistor.
The impedance of the electret mic is about the same as the input impedance of the transistor but the mic needs about 0.5mA to operate and the voltage on the base of the transistor needs to be very accurately set for "self bias." A capacitor separates these slightly different DC values while passing the AC signal..

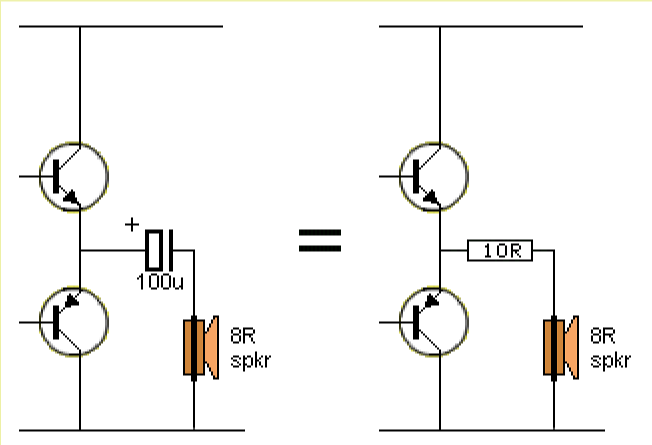


Fig 71e

Sometimes Impedance Matching is needed to separate or remove the DC component of a signal. In **Fig 71e**, the electrolytic matches the LOW IMPEDANCE output of the amplifier to the LOW IMPEDANCE of the speaker. The two impedances are almost identical and you could connect the speaker directly to the output of the amplifier, but the output has a voltage of approx mid-rail and this would enter the speaker and shift the cone when no audio is being reproduced. And the speaker would only be able to amplify the negative part of the waveform.
To remove the DC component of the waveform, an electrolytic is included.

SATURATING A TRANSISTOR

This is the last topic for discussion because it is the last thing to attend to when designing a circuit.
We have explained the fact that a transistor turns ON when the base voltage is above 0.7v and the current though the collector-emitter leads is approximately 100 times the base current.
This means a transistor with a gain of 100 will deliver 100mA to a collector LOAD when 1mA enters the base.
This is theoretically true and will occur in nearly all cases, but some devices such as motors and globes need a lot more current to get them started or to get them to turn **ON** because the cold resistance of a globe is only about 1/5 its hot resistance. This means a 100mA globe needs 500mA to get it to start to glow.
The same with a motor. The starting or "stalled current" is 5 times more than the operating or "running current.
On top of this the transistor might not have a gain of 100 and the voltage may be slightly higher than expected. All these things means the transistor must be turned **ON** with more than 1mA into the base.
If you deliver 2mA, it does not mean the transistor will deliver 200mA to a LOAD. If the load requires 100mA, delivering 2mA to the base will simply turn the transistor **ON** harder and the collector-emitter voltage will be slightly lower, but the load will still draw (or take) 100mA.
But the devices we mentioned above require 500mA to get them started, so the base current needs to be 5mA.
Now, here's the unfortunate part, 5mA base-current will not deliver 500mA collector current. The transistor needs more than 5mA base-current to get it to deliver this HIGHER current. It needs about 7mA.

This process can be proven by experimentation.
Simply increase the base current until the device is turned **ON**, then measure the base current. Add 1mA to 3mA to guarantee reliability and the circuit is complete.
This process is called **SATURATING A TRANSISTOR** or **GUARANTEEING TURN-ON**, or **FULLY SATURATING the TRANSISTOR** or **FULLY TURNING the TRANSISTOR ON**.

HYSTERESIS

Hysteresis is a feature of a circuit. It is when the circuit turns on at a particular voltage and turns off when a higher or lower voltage is reached. The gap between these two voltage-levels is called the **HYSTERESIS GAP.**
This is a very handy feature.
It prevents an effect called "hunting."
If a circuit turns on at say 6v, and turns off at 5.7v, any slight variation in the supply voltage will cause

the output to change state. This may produce an undesirable effect of the circuit turning "on and off" at the wrong time due to supply voltage fluctuations. By increasing the gap between these two voltages, the circuit will remain in one state or the other - until the input voltage (the controlling voltage) increases or decreases.
The **Schmitt Trigger** (Fig 79a) is an example of a circuit using **Hysteresis**.
Any circuit with a positive feedback line, introduces the effect we are talking about.
The feedback line has the effect of assisting the input voltage.
In other words, it widens the gap between an ON state and an OFF state.
This is called POSITIVE FEEDBACK because it ADDS to the effect of the input voltage.
Even when the input voltage is falling, the feedback improves the ON or OFF state by taking the circuit past the point where the change takes place.
Rather than thinking of the feedback as "positive," consider it as AIDING.
All **HYSTERESIS** feedback is **AIDING** or **ASSISTING** the effect you are trying to produce.

This circuit uses Hysteresis. The main "assisting component" is the 22k.

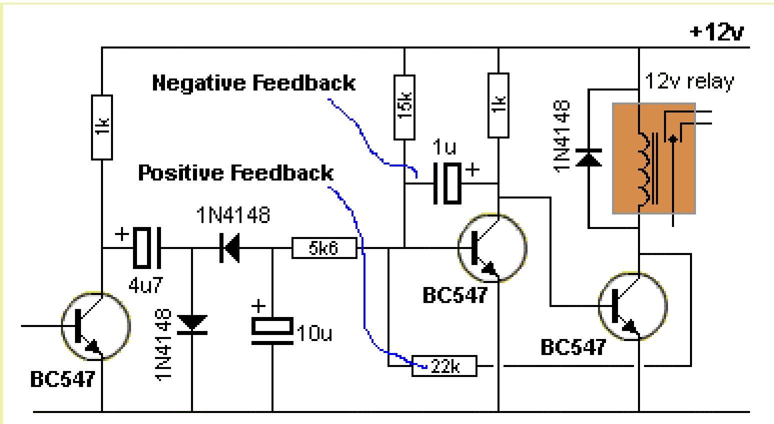
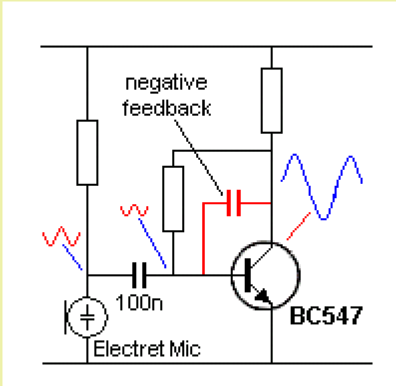


Fig 103cc

This is how the circuit works:
When the circuit is turned on, the base of the second transistor gradually develops 0.6v and the transistor turns ON.
The voltage between collector and emitter is about 0.2v and the third transistor is OFF.
When the first transistor receives an AC signal, an increasing voltage on the base causes the collector voltage to reduce and the charged 4u7 electrolytic moves towards the 0v rail. The negative lead of the 4u7 goes below the 0v rail by about 0.6v.
This allows the second diode to discharge the 10u electrolytic and the 0.6v on the base of the second transistor is reduced. Let's say it is reduced to 0.55v.
This causes the second transistor to turn off and the positive lead of the 1u electrolytic rises toward the 12v rail. The negative lead of the 1u rises too and this makes the transistor turn ON. In this process the 1u starts to charge and it has the effect of slowing down the "turning ON" of the second transistor.
But the pulses keep coming from the first transistor and 10u is kept discharged. The 1u keeps charging and eventually it is fully charged and now the pulses from the first transistor can finally turn off the second transistor.
The third transistor is turned ON and the 22k connected to the collector of the third transistor reduces the voltage on the base of the second transistor by about 0.15v
This helps the pulses from the first transistor to keep or put a low voltage on the base of the second transistor and even if these pulses stop, the voltage on the base will take time to rise via the 15k and this is called the **HYSTERESIS GAP.**
When the circuit changes state, the pulses from the first transistor will discharge the 10u and this will be "fighting against" the 15k and 22k resistors that will be trying to charge the 10u.

NEGATIVE FEEDBACK



The circuit shows a capacitor between the base and collector. It provides **NEGATIVE FEEDBACK.**
If we remove the capacitor, when the base "moves down," the collector "moves up." In other words the signal is inverted.
When the capacitor is fitted, we have to start with the collector because it has more "power" and it is the lead that is driving the action of the capacitor and then go to the base.
When the collector voltage "moves down" the right plate of the capacitor moves down and it charges and tries to pull the left plate down too.

This is the opposite effect to the signal moving through the transistor.
This means the capacitor is working against the action of the transistor.
The capacitor will have more effect on high frequency signals while the low-frequency signals will be affected less.
Because the capacitor is working against the natural flow of signal through the circuit, it is called NEGATIVE ACTION or **NEGATIVE FEEDBACK**.

BIASING THE BASE

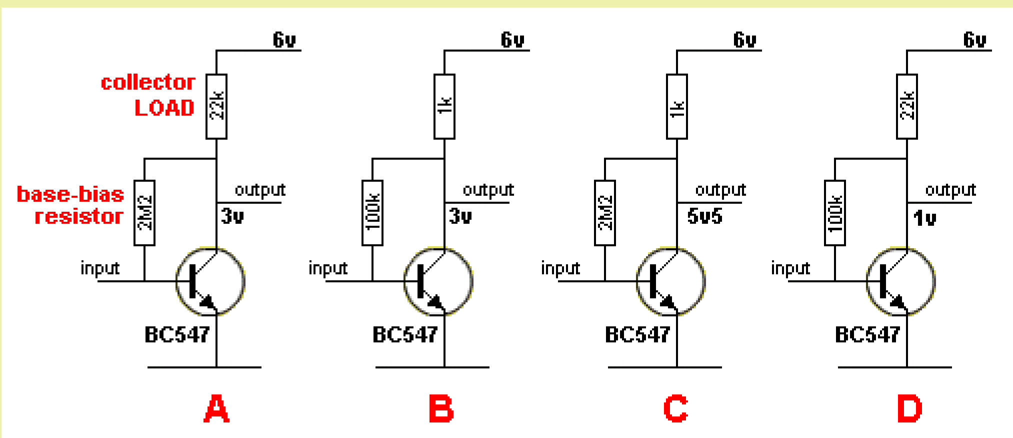
The base of a transistor can be biased in many way. In other words, the current to be supplied to the base can come from many different parts of the circuit and delivering it is much more complex (complicated) than you think.
This discussion has been intentionally put at the end of this eBook so you already have an understanding of how a transistor can be biased and have seen a number of different ways to bias it.
We will now cover some of the ways to bias a base without getting too technical but you must remember, this is a very technical area and the results you will get will depend on the type of transistor used.
Since the range of current requirements for the base of a transistor can be 1,000 times more than our discussion, you have to use the skills we provide, to work out how to finalise the circuit you are designing.
Here are a few fundamentals you need to remember:
We will consider a transistor has a gain of about 100 in a "self-biased" stage. (It can be as low as 10 or as high as 200).
This means the collector-emitter circuit can only deliver 100 times more current than is being supplied to the base.
But current supplied to the base is "wasted current" as it flows ALL THE TIME and for battery operated circuits, this current must be kept as low as possible.
Secondly, a transistor can only deliver current up to the maximum rated value for the transistor. If the maximum current is 100mA, a current of 1mA into the base will allow the transistor to deliver 100mA via the collector-emitter circuit. That is: the load can take 100mA. But as the current reaches the maximum value, the transistors gain decreases. This means a base current of 1mA will only allow the transistor to deliver about 50mA. As the output current requirement increases above about 50%, the base current must be increased.
This is one of the hidden problems with a transistor. It may take 2mA base-current to get to 70mA, 5mA to get to 80mA and 10mA to get to 100mA.
This is a big difference as the gain can drop from 100 to 10.
This is one of the factors you have to be aware of.
That's why the gain of a transistor is generally given for 10mA collector-current.

Working out the value for the base current is a big problem and we are going to cover only the small-

signal stage.

BASE CURRENT

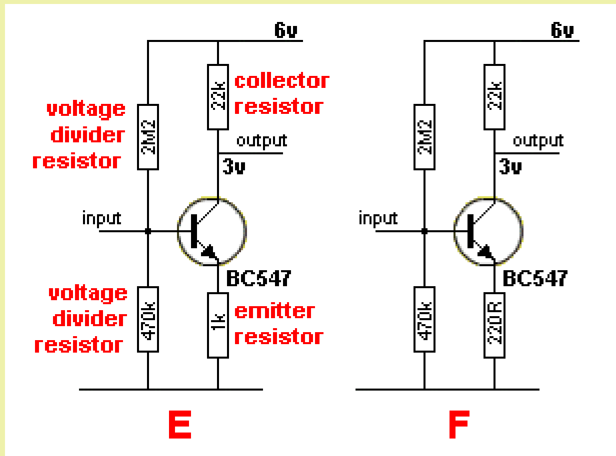
The following 4 diagrams show how base current is delivered to a small-signal stage in a "self-biasing" arrangement.
In this arrangement, the **base-bias resistor** is selected so the voltage on the collector is half-rail voltage. In this case it is 3v.
Circuits **A** and **B** have 3v on the collector.
But circuit **A** takes less current when "sitting around." Circuit **B** takes 22 times more current. This is due to the collector load.
Why select circuit **A** or **B**?
We have already learnt the current delivered to the next stage in a circuit depends on the current flowing through the COLLECTOR LOAD resistor. Refer to **Fig 13** and **Fig 62.**
This means circuit **B** will deliver more current.
One other factor you have to remember, is this: Circuit **A** requires a very small input current. Circuit B requires about 20 times more current. You can think of it this way: The input energy (that is the input voltage-and-current) is "fighting against" the base-bias resistor. It is much-easier to fight-against a 2M2 resistor as it is delivering much less current (to the base) than a 100k resistor.
Let's explain what we mean by "fight against."
For circuit **A**, the 2M2 is delivering current to the base. When the input current increases, the transistor is turned on MORE and the collector voltage falls. This means the current via the 2M2 reduces. This means you have to supply more base current to turn the transistor on.
Circuit **B** has a 100k base-bias resistor but the main criteria in turning the transistor ON is the large amount of current required by the base to get current-flow in the collector-emitter circuit so that a voltage-drop is developed across the 1k resistor. 22 times more current is required to get the same voltage-drop produced in circuit **A**.
Circuits **C** and **D** show the wrong combination of resistors, making the collector voltage too high or too low. If it is too high or too low, the stage will not (equally) amplify the positive and negative excursions of the input signal. However, this may be what you want.



"Self Biased" stage

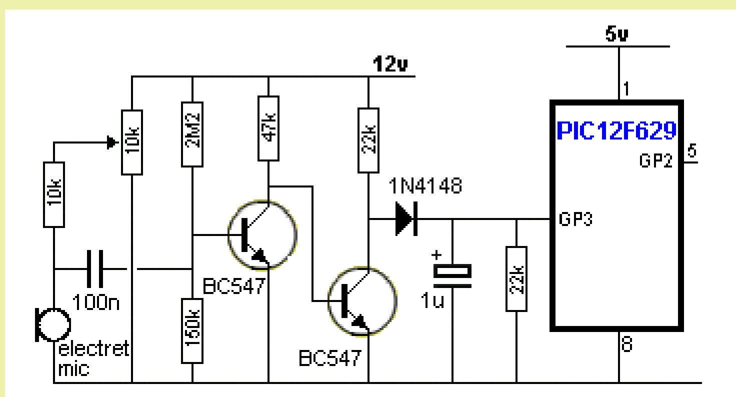
The second type of biasing is called a "Bridge" or "H-Bridge." Circuits **E** and, **F** show two bridge circuits.
Circuit **E** is very similar to circuit **A**. It needs about the same input current to circuit **A** and has about the same output-current capability.
However circuit **E** has a gain of about 22. Circuit **A** has a gain of about 70 to 100.
The gain of circuit **E** is defined as collector resistor divided by emitter resistor 22k/1k = 22.
The gain of circuit **F** is about 100.

Circuits **A** and **F** produce about the same gain and the only difference is two extra resistors in circuit **F**.
The only problem with circuits **E** and **F** is the rail voltage must be above 4v. If the rail voltage is less than 3v, the transistor will not be turned ON as the base will see less than 0.6v. The "self biased" stage will operate down to about 1v rail-voltage.



"Bridge" stage

The third type of circuit is biased just below the voltage needed to turn the transistor ON.
This stage takes very little quiescent current but the supply voltage cannot rise a large amount as this will turn the transistor ON and change the characteristics of the stage.



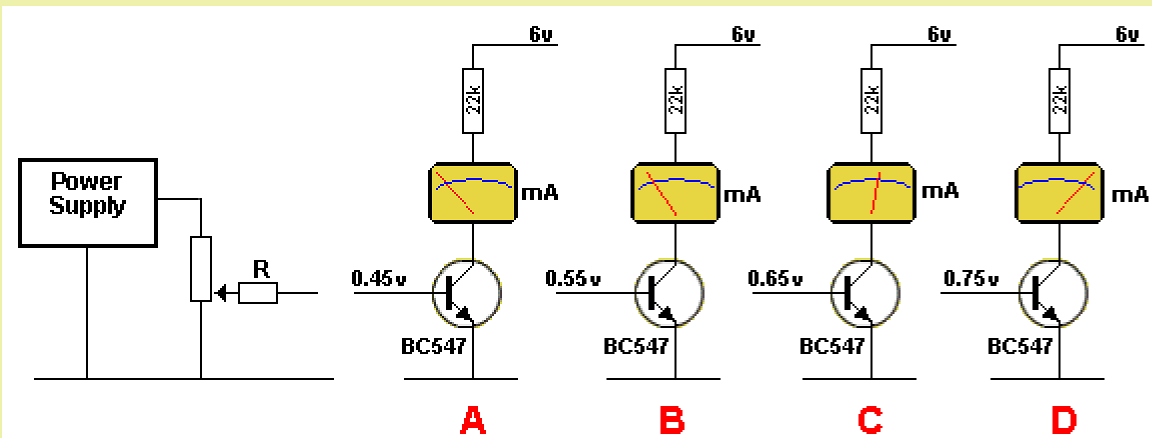
The first transistor is biased "OFF"

The starting point is to bias the first transistor so the voltage on the base is just at the point of turning it ON.
This allows the 47k resistor to turn on the second transistor and the diode does not see any voltage.
This means the 1u does not get charged and the input to the microcontroller sees a LOW.
This is called the QUIESCENT (standing, stand-by or idle) condition.
The gain of the electret microphone is adjusted by the 10k pot and when it receives a loud audio signal it produces an output of about 20mV.
This signal is sufficient to turn ON the first transistor and turn OFF the second transistor so that signal diode sees a HIGH pulse via the 4k7.
This voltage is passed to the 1u and it gradually gets charged. When the voltage on the 1u reaches about 4-5v, the microcontroller sees a HIGH and the program in the micro produces an output.
The main problem with this circuit is the 20mV required to turn on the first transistor.

Different transistors have varying base voltages. You will need to set the base voltage very accurately for the circuit to work.

What do we mean by: **DIFFERENT BASE VOLTAGES**?
Most silicon transistors start to turn ON when the base voltage reaches 0.65v. But some transistors start at 0.55v. And some transistors are fully turned on at 0.7v while others need 0.75v.
These different voltages are not important in most cases except for the circuit above that keeps the transistor turned off until required.

We are now going to show how a transistor TURNS ON. In this discussion, the base voltage is delivered from an adjustable power supply
An NPN transistor is not turned on AT ALL when the base voltage is below 0.45v. This is shown in diagram **A**:

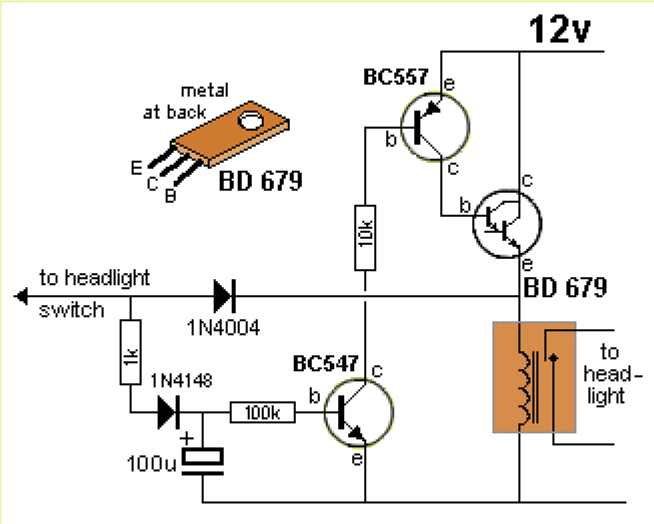


As soon as the base voltage reaches 0.55v, the transistor starts to turn ON. This is shown in diagram **B**.
A transistor is a current-controlled device and this is how it works:
As the voltage from the power supply is increased from 0.50v to 0.55v, current will start to flow into the base and the transistor will start to turn ON. The transistor will turn on MORE when the base voltage rises to about 0.65v.
The value of 0.65v shown in diagram **C** just lets you know the transistor is turned on a certain amount. It's a characteristic voltage produced by the transistor that we have no control over.
When we read this voltage we know the transistor is a point of just being turned ON. Another way to look at the situation is this: The transistor detects how much current you are delivering from the power supply and it delivers about 100 times this amount through the collector-emitter circuit.
Here's the highly technical part: The voltage from the power supply must be CURRENT-LIMITED. This is done by adding the resistor **R**. The voltage from the power supply flows through resistor R and allows the transistor to develop a base voltage called a CHARACTERISTIC VOLTAGE or BASE VOLTAGE. This is a voltage developed by the transistor when a certain amount of current is flowing and by measuring this voltage we know how much current it is receiving. Adding the resistor allows the transistor to take the amount of current it requires. If we connect the power supply directly to the base, we will force extra current into the base and over-ride the natural requirements of the transistor.
As you increase the voltage from the power supply, more current will enter the base and the voltage on the base will rise slightly to indicate the new value of current. This is shown as 0.75v in diagram **D**.
The transistor will deliver more current through the collector-emitter circuit, but as the current increases to a maximum value (every transistor has a maximum allowable collector current), it may not be able to deliver 100 times more than the base current. It may be only 50 times or 10 times.
Increasing the current (further) into the base will have no effect on the base voltage. The base voltage is as high as it will go. The transistor is SATURATED (turned ON as hard as possible) and no

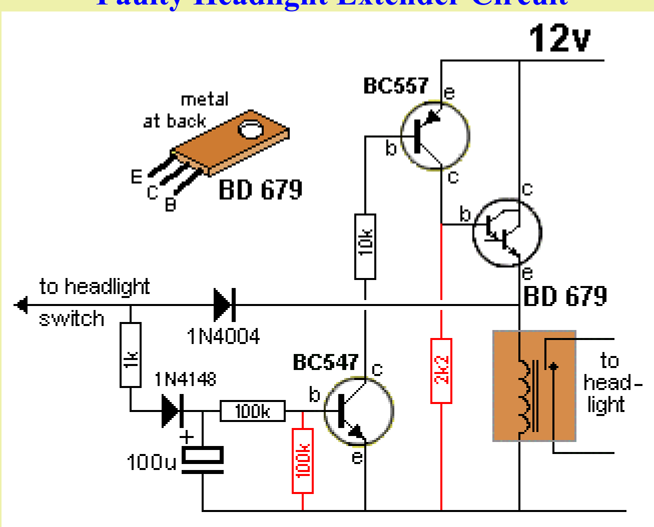
further increase in collector-emitter current is possible. Increasing the current into the base will simply overheat the transistor and damage it.

LEAKAGE

This topic covers small, unwanted, currents produced when two or more transistors are connected together.



Faulty Headlight Extender Circuit

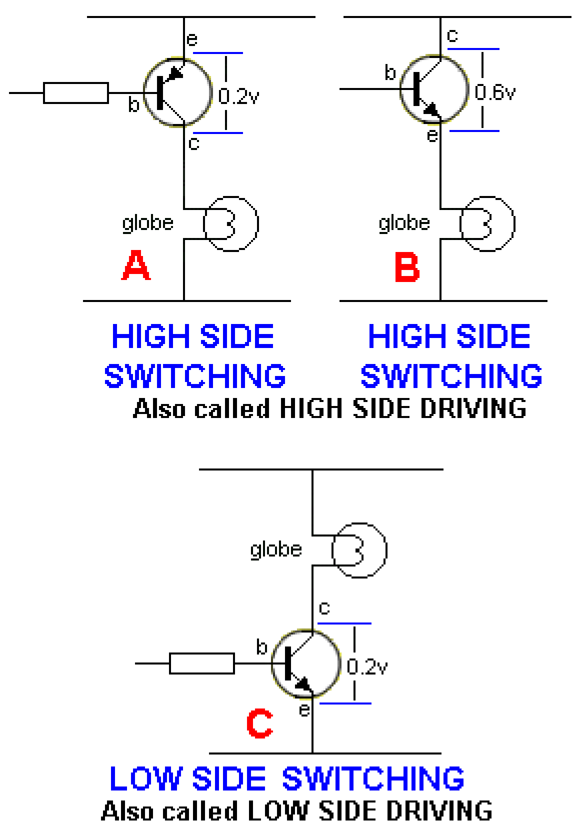


Headlight Extender Circuit - fixed

In the Faulty Headlight Extender Circuit we see 3 transistors directly connected together.
When the 100u discharges, the BC547 turns OFF and this turns off the BC557 and also the BD679.
But the relay remains activated.
This is due to the BC547 not turning off fully and a very small current flows though the collector-emitter leads.
This current is amplified by the BC557 (about 200 times) and then by the BD679 (about 20,000 times). The resulting current is sufficient to keep the relay activated.
Two resistors are needed to turn the circuit off.
The 100k on the base of the first transistor discharges the 100u and makes sure the voltage on the base is zero so the transistor is fully turned off.
The 2k2 on the base of the BD679 does not remove the slight leakage current though the BC557 but it flows through the 2k2 and this produces a very small voltage-drop, that is too small to turn on the BD679, and this makes sure the BD679 turns off.

This type of problem will occur whenever two or more transistors are directly coupled together.
Even a leakage current of less than 1microamp will amplify to many milliamps with the gain of two or three transistors.

High-side Vs Low-side Switching



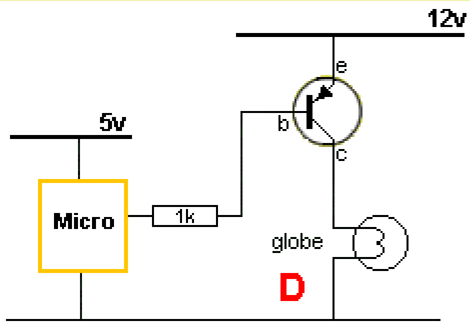
Devices such as globes, motors, relays etc are called LOADS. They can be placed above or below the driver transistor. When the driver transistor is above the load, as shown in diagrams A and B the circuit is called **HIGH-SIDE SWITCHING**. When the driver transistor is below the load, as shown in diagram C, the circuit is called **LOW-SIDE SWITCHING**.

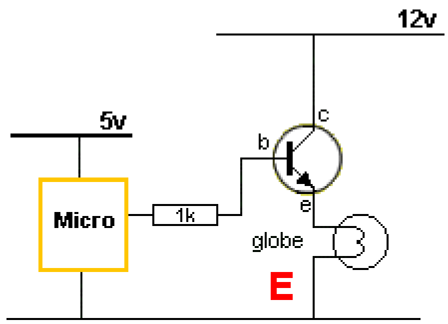
The circuit for low-side switching is much easier to design and can be less expensive however high-side switching is the only arrangement available in cars and trucks as the load (globes and motors) are generally connected to chassis (to save wiring) and the control wire (power wire) comes from the positive of the battery.

For the **HIGH-SIDE SWITCHING**, the control line (the input to the base) can be active LOW (as in the first diagram). In the second diagram, the base is taken HIGH and the emitter follows. The voltage across the collector-emitter terminals will be higher than the fist example and the transistor will get hotter. This is because the base of the NPN transistor cannot rise above the supply (in most cases such as cars and trucks) and the voltage between collector and emitter will be about 0.65v.

The three diagrams above show the voltage across the collector-emitter leads when the transistor is fully conducting.

In diagram **B** the transistor is an emitter-follower and the voltage is three times larger than diagrams **A** and **C**. This means the heat generated by the transistor will be three times larger than diagram **A** or **C**.





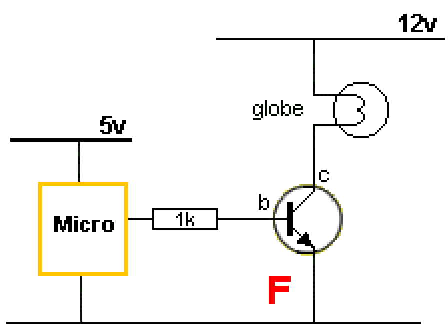
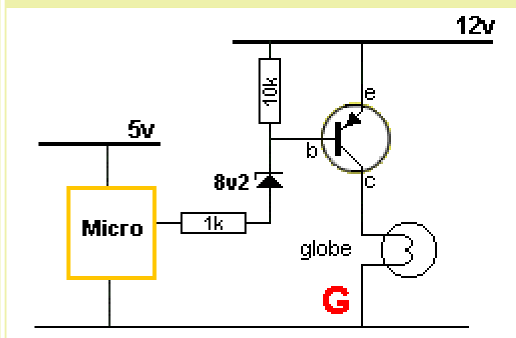


Diagram **D** shows the problem trying to switch a load on a 12v supply, from a 5v microcontroller. When the microcontroller is HIGH, the voltage is not high enough to turn off the transistor. The voltage on the base must be nearly 12v for the transistor to turn off.
This circuit will NOT WORK.
In diagram **E**, the voltage on the base will only rise to 5v,
and thus the globe will see only 4.4v and will not illuminate fully. The transistor will get fairly hot.
The solution is to drive the LOAD via LOW SIDE SWITCHING as shown in diagram **F**.

It is possible to switch a HIGH SIDE transistor from a microcontroller by including a zener diode so the transistor is turned off when the microcontroller is HIGH. The 10k resistor makes sure the base sees 12v when the micro is HIGH. The voltage of the zener is chosen so that when the micro is HIGH, the micro rail voltage, plus the voltage of the zener is more than the supply to the globe.



VOLTAGE TO CURRENT CONVERTER

This sounds very complex but it is very simple.
The simplest voltage-to-current component is a resistor.
A resistor performs lots of different jobs, depending on the circuit.
One of its jobs limits the current to a LED. It is called a CURRENT LIMITING RESISTOR. It can also be called a VOLTAGE TO CURRENT CONVERTER.
Here's how it works:

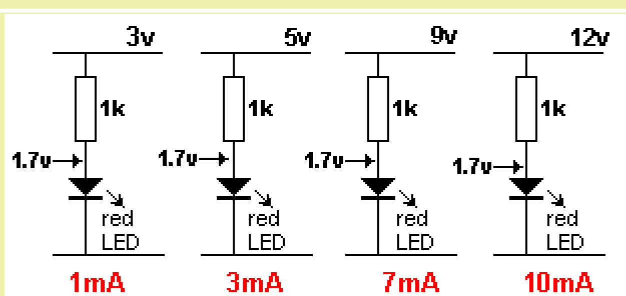


Fig 103d.

A resistor is a **VOLTAGE TO CURRENT CONVERTER**

A red LED must be delivered a voltage of exactly 1.7v for it to work. In other words it must be connected to a 1.7v supply.
But a 1.7v supply is very hard to obtain, so we use a 3v supply and a dropper resistor.
The resistor converts the 3v to 1.7v.
This is easy to understand because the 3v supply is fixed at 3v and when a voltage is delivered to the red LED it develops exactly 1.7v across it. The resistor sits between the 3v and 1.7v
When the voltage of the supply is increased, The voltage across the LED remains at 1.7v and the voltage across the resistor increases. This is shown in the diagrams above.
When the voltage across a resistor increases, the current through it increases. That's how we get 3mA, 7mA and 10mA. This is called VOLTAGE TO CURRENT CONVERSION.
The VOLTAGE on the input goes up and down and the CURRENT through the LED goes up and down.
The input CURRENT will also go up and down but we are only covering the fact that the input VOLTAGE rises and falls and the output CURRENT RISES and falls.
Any circuit that produces this effect is called a VOLTAGE TO CURRENT CONVERTER.
A transistor can also be connected to produce VOLTAGE TO CURRENT CONVERSION.
The following circuit is an emitter-follower. It is also a VOLTAGE TO CURRENT CONVERTER. A rising and falling voltage on the input creates a rising and falling CURRENT on the output.
It also produces a rising and falling voltage on the output but we are only concerned with the fact that the circuit produces a rising and falling **CURRENT** on the output when the input **VOLTAGE** rises and falls.

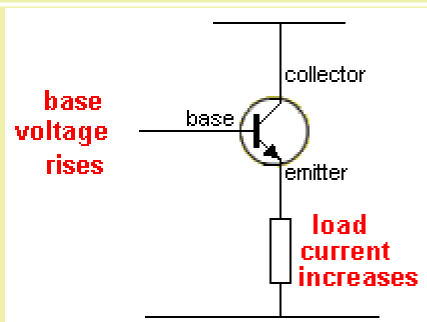


Fig 103e.
An emitter-follower is a **VOLTAGE TO CURRENT CONVERTER**

The circuit in **Fig103e** requires say 1mA input current. The output current will be 100mA. The circuit has the capability of increasing the current or AMPLIFYING the current. The resistor circuit above does not AMPLIFY the current. It is only a voltage-to-current converter.
The transistor performs a VOLTAGE TO CURRENT CONVERSION and also produces CURRENT AMPLIFICATION.
A common-emitter stage also performs VOLTAGE TO CURRENT CONVERSION.

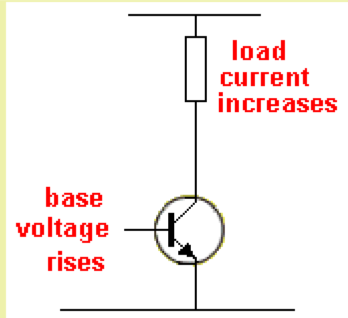


Fig 103f.
A common-emitter stage is a **VOLTAGE TO CURRENT CONVERTER**

A slight increase in the voltage on the base of a common emitter transistor will increase the current through the load by a large amount.
As you can see, there are lots of circuits that perform VOLTAGE TO CURRENT CONVERSION but we usually identify them for other features and that's why the term VOLTAGE TO CURRENT CONVERSION is rarely mentioned.
There are also special circuits (using op-amps) to perform precision voltage-to-current conversion, but we are concentrating on transistor stages.

CURRENT TO VOLTAGE CONVERTER

A resistor can be used as a **CURRENT TO VOLTAGE CONVERTER**.
Fig 103g shows a resistor called a **SENSE RESISTOR**.
It is a low-value resistor in series with one line of a circuit and its function is **not to change** the operation of the circuit in any way.

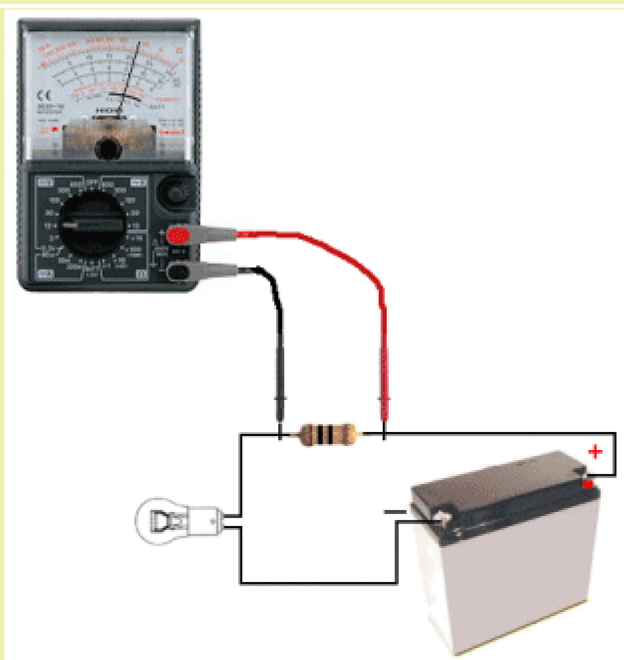


Fig 103g. Measuring the "sense resistor"

Its function is to produce a very small voltage across it and this voltage is detected by a circuit (basically a voltmeter (or milli voltmeter).
When a current flows though a resistor, a voltage is produced across the resistor. You can also say a **VOLTAGE DROP** is produced across the resistor. If the resistor is exactly 1 ohm, a voltage of 1v will be produced across it when 1 amp is flowing or 1mV is produced for each 1mA of current. Using a 1 ohm resistor produces an easy conversion.
If the circuit is 24v or 50v, a loss of 1 volt will not be noticed.
But if the circuit has a lower voltage, (say 5v) the resistor will be need to be a lower value so the drop across the **sense resistor** does not upset the operation of the circuit.
The actual value of the resistor is not important for this discussion, It can be 1 ohm or 0.1 ohm.
The important point is to understand the function of a **Sense Resistor**.
In the circuit above, if the globe is replaced by a 20watt or 50watt, globe, the current through the sense resistor will increase. We measure the voltage (in millivolts) across the resistor and we convert the value into CURRENT. This is a CURRENT to VOLTAGE CONVERSION.
A transistor can be used as a CURRENT TO VOLTAGE detector. **Fig 103h** shows a 1 ohm sense resistor connected to a transistor. When the circuit is turned ON, the charging current (the current flowing into the battery) will be high and when the voltage across the **sense resistor** reaches 0.65v, the transistor turns ON and the voltage on the collector reduces. This turns on the red LED and reduces the voltage on the ADJ terminal of the LM317T regulator and the regulator outputs a lower current to the batter. This is how the circuit limits the charging current. The resistor is **converting** the current flowing through the circuit (and into the battery) into a voltage, and the transistor detects the voltage. The transistor is not detecting or measuring the current. It has absolutely no idea of the amount of current flowing. It is detecting the voltage across the resistor. The resistor is performing the **CURRENT to VOLTAGE** conversion.

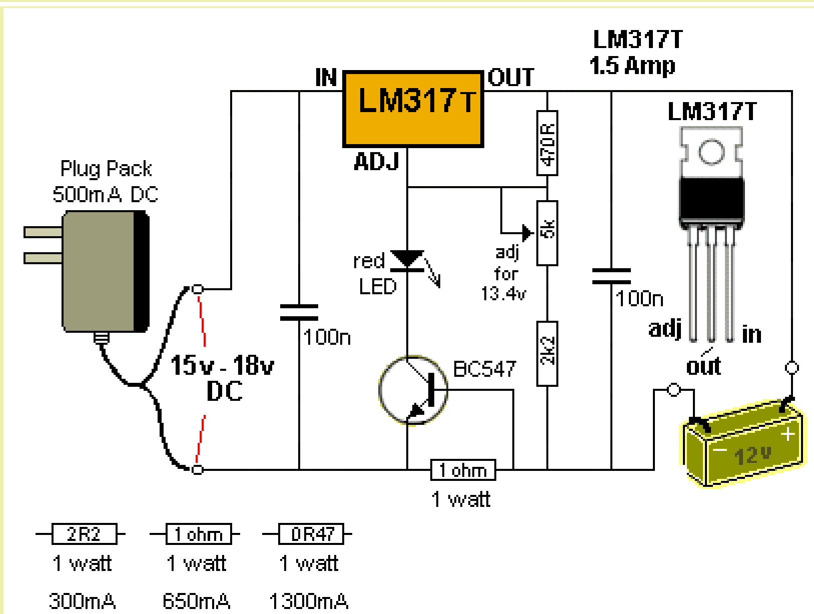


Fig 103h. The 1ohm Sense Resistor.

SQUEALING, BUZZING, OSCILLATING, and MOTOR-BOATING

We have studied **POSITIVE FEEDBACK** and the effect it produces. It turns an amplifier into an

oscillator.
The following circuit will not work:

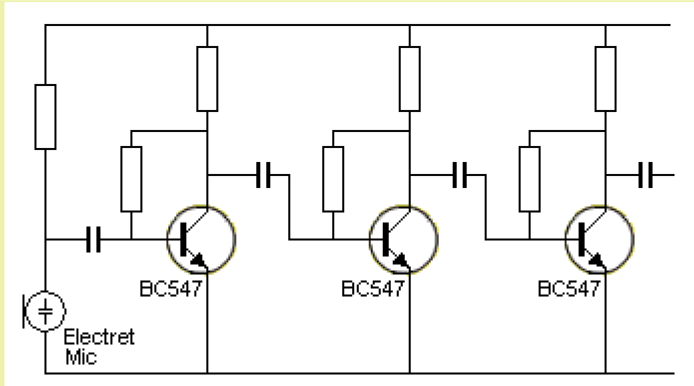


Fig 104a.

The three stages of amplification will produce so much gain that the circuit will self-oscillate. The output will be a "buzzing-sound" and the fault will be impossible to find because it comes from **within** the design of the circuit. The first thing you must do is add "power-supply decoupling."
The unwanted sound produced by the circuit is called **MOTOR-BOATING** and is generated in the "front-end" by very small noises or "disturbances" and amplified by the stages that follow.
Fig 104b shows where the noise starts. It can be produced by the electret microphone or by the noise in the junctions of the first transistor (due to current flowing in the collector-emitter circuit).

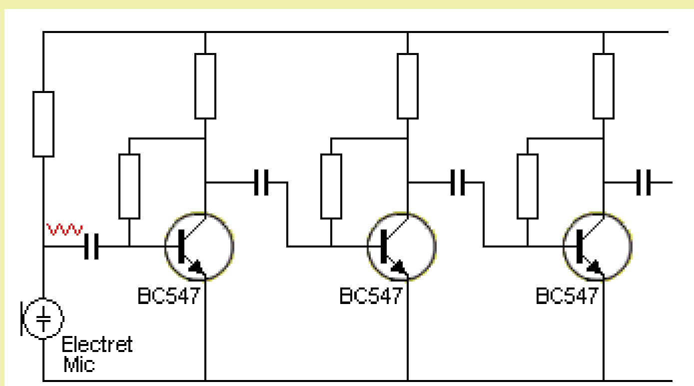


Fig 104b.

This waveform will be very small and almost impossible to detect via any test-equipment, but it will start in the first stage and pass through the coupling capacitor as shown in **Fig 104c**.
The next stage will amplify this "noise" and it will be amplified further by the following stages.
There will be some slight cancellations from the various stages as the signal will be "out-of-'phase" but the end result will be a "putt-putt-putt" or squealing from the output.
The general term for this is called MOTOR-BOATING and is due to the high gain of the circuit.
The noise will appear on the power rail and get passed to the front-end where it will be amplified more.

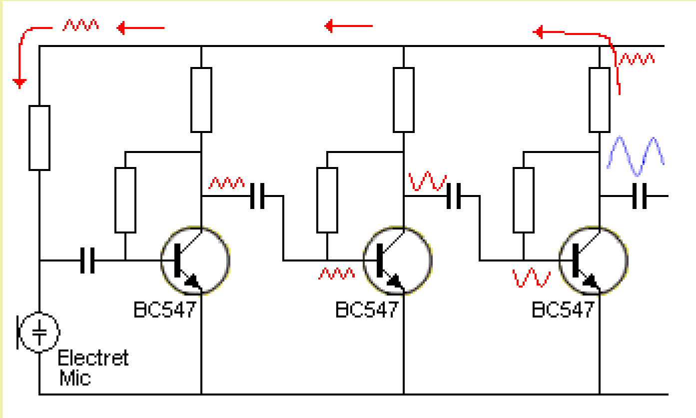


Fig 104c. The positive feedback loop producing "Motor-boating"

This effect can be reduce and eliminated by a term called **DECOUPLING**.
Decoupling is achieved by adding capacitors [electrolytics] (and resistors) across the power rails so that each stage is effectively powered by a separate supply.
Adding an electrolytic can sometimes make a big difference and sometimes it will make no difference. It all depends where it is connected and the value.

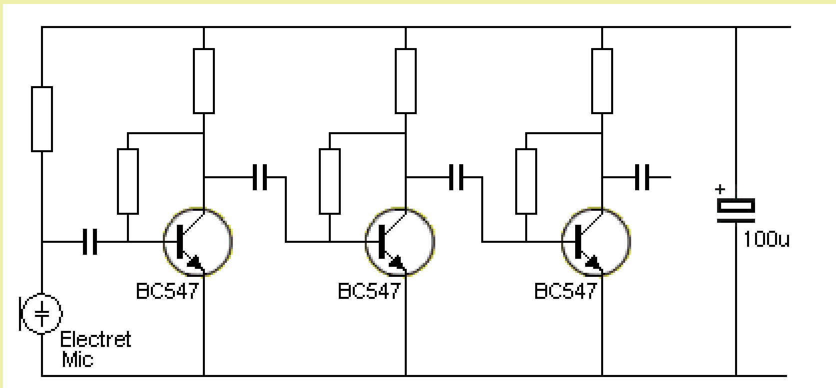


Fig 104d.

Fig 104d shows an electrolytic connected across the power rails. This is called **DECOUPLING THE POWER RAILS** and effectively tightens up the power rails so that any noise on the positive rail is removed.
But, as you can see, the power rails extend to the first transistor and although the rails may be "tight" near the battery they can "move" near the first stage.
This is due to the wiring between the stages or the tracks on the PC board. That's why an electrolytic across the battery may have little effect on removing our motor-boating problem.

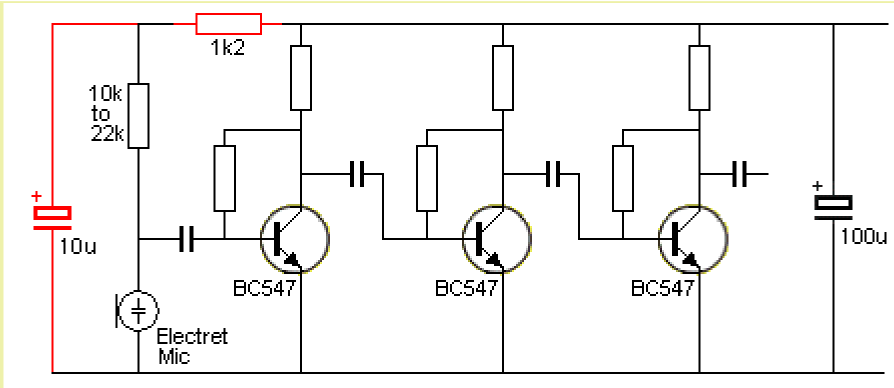


Fig 104e.

Fig 104e shows an electrolytic connected across the supply that feeds the electret microphone and 1k2 resistor to separate the supply we have just created, from the main supply rail.
We have effectively created a separate power supply. It is fed by a 1k2 and kept "tight" by the 10u capacitor.
The electrolytic does not have to be a high value because the electret mic takes very little current and the voltage-waveform (the AC signal) produced by the microphone is very small (about 20mV).
These two items **very effectively** decouple the microphone from the supply rails so the microphone has its own supply. The 1k2 resistor does most of the "separation." The voltage-drop across it will be very small and it will not affect the operation of the circuit, but the small voltage-drop will prevent any noise on the power rails being fed to the microphone via the 10k resistor.

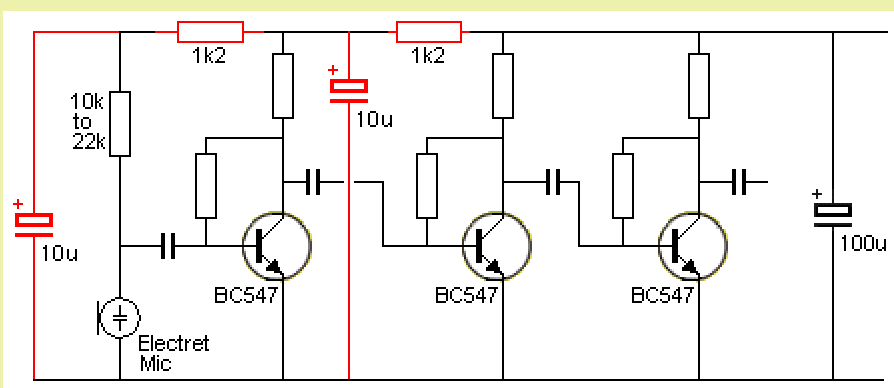


Fig 104f.

To remove any slight motor-boating problems (if they still exist); a power-supply filter (called power-supply decoupling) made up of a 1k2 and 10u can be placed after the first amplifier stage as shown in **Fig 104f**.
By selecting the value of capacitance and resistance, this arrangement will remove almost all motor-boating problems. It is a very-effective form of suppression.
Decoupling is most-effective on the pre-amplifier stages, however every circuit is different and these two components only deal with the low-frequency motor-boating type of instability. Some circuits also produce high-frequency oscillations (about 1MHz) and these need removing by a different value of capacitor-feedback.

BREAKDOWN and ZENER MODE

There are two conditions or states where a transistor can be instantly damaged. This is due to voltage applied in the wrong direction or the application of voltage that is higher than the rating of the transistor.
Voltage will kill a transistor faster than excess current.
A high voltage spike can damage a transistor instantly.
However if the excess voltage does not have enough current to damage the transistor, it will recover and we can use this feature in a circuit.
Breakdown and zener mode are different.
In **breakdown mode**, suppose we have a transistor that has a specification of 85v for the voltage it will withstand between the collector and emitter as shown in Fig 104g:

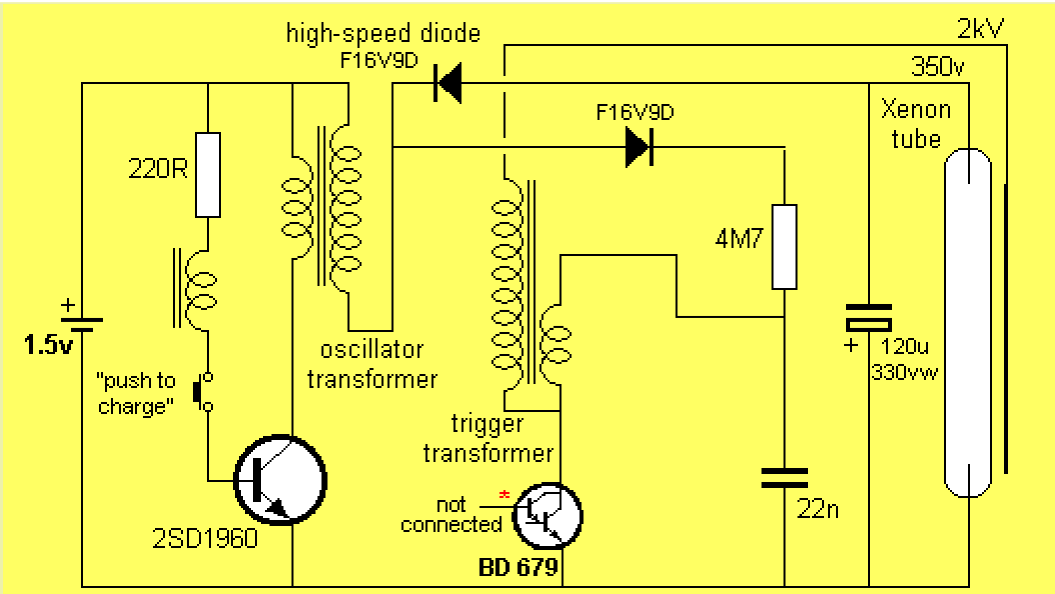


Fig 104g **XENON FLASHER - FLASH CIRCUIT**

It will "resist" a voltage of 85v and this voltage will appear across the collector-emitter leads. When the voltage increases to 86v, 87v ... the transistor will suddenly breakdown and only a few volts will appear across it. This fires the trigger transformer in the circuit above.
If the current is very small, the transistor will not be damaged and when the voltage is removed and a lower voltage applied, it will operate as an undamaged device.

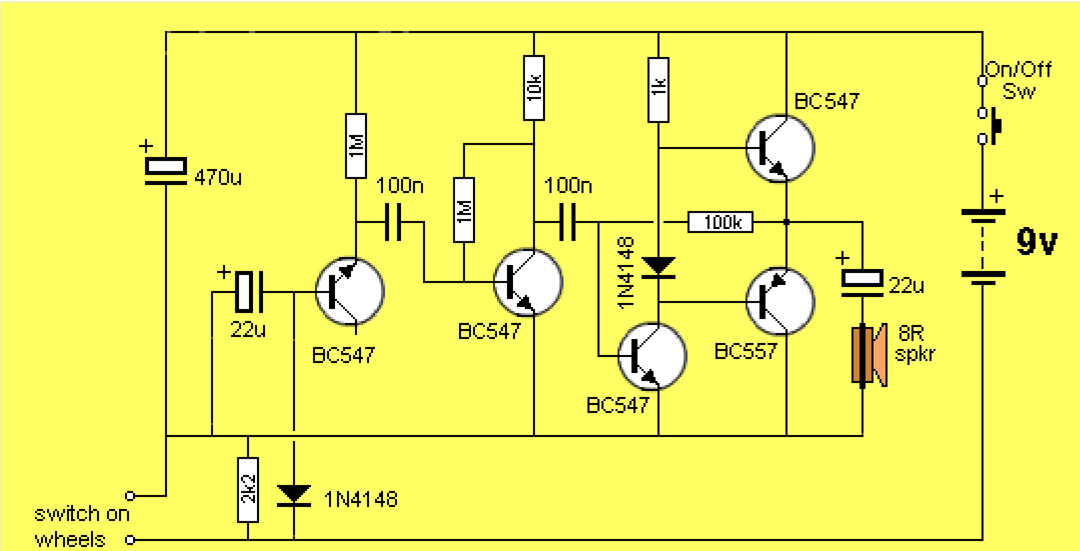
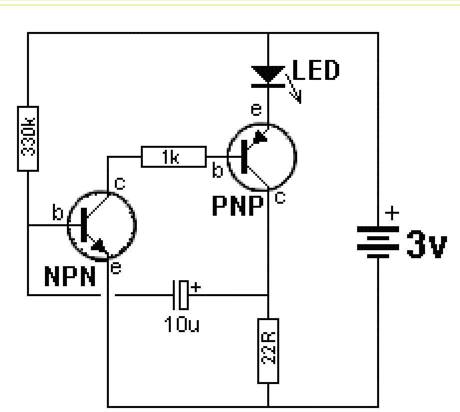


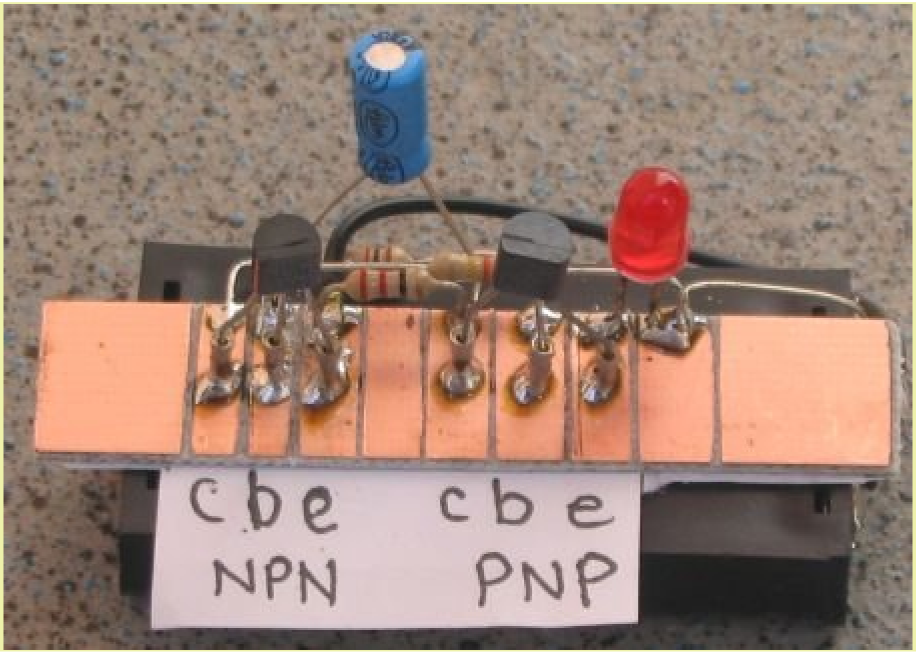
Fig 104h **STEAM ENGINE SIMULATOR**

In **zener mode**, the base-emitter junction is connected to a voltage higher than 9v via a resistor. The junction will breakdown and a voltage of about 7v will appear across the base-emitter leads and the excess voltage will be dropped across the resistor.
The zener-effect or zener mode can be used to produce white noise or a 7v zener reference. **Fig 104h** shows the first transistor with the base-emitter junction reverse-biased to produce a "noisy zener" via the 1M feeder resistor. The noise is picked off via the 100n and amplified by the remainder of the circuit.

TRANSISTOR TESTER

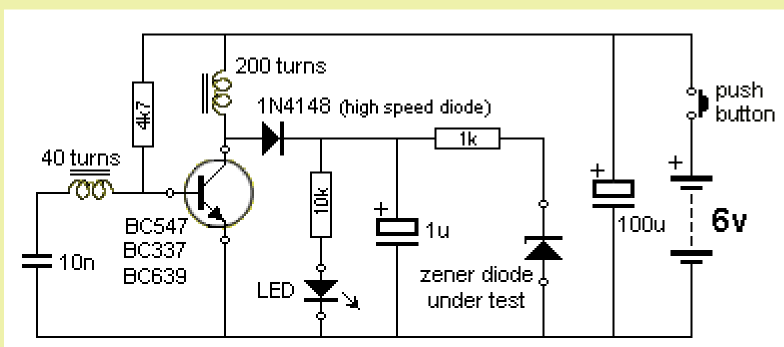


This circuit is basically a high gain amplifier with feedback that causes the LED to flash at a rate determined by the 10u and 330k resistor.
Remove one of the transistors and insert the unknown transistor. When it is NPN with the pins as shown in the photo, the LED will flash.
The circuit will also test PNP transistors. To turn the unit off, remove one of the transistors.



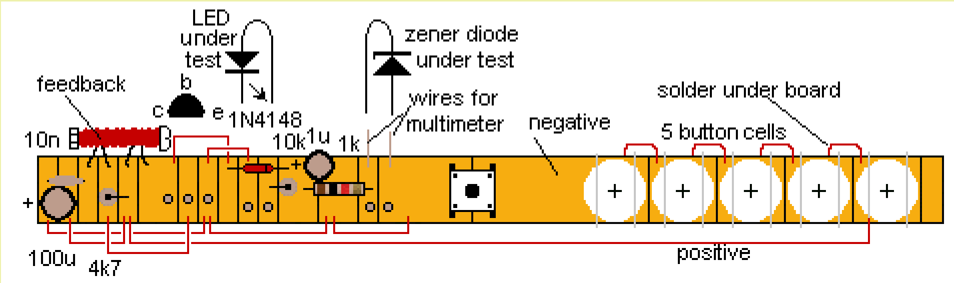
ZENER TESTER

The maximum voltage a transistor can withstand is called the ZENER VOLTAGE of the transistor.
It is Vce - the voltage between (across) collector and emitter. It is also the maximum supply voltage or circuit voltage or the voltage generated by an inductor in the collector-circuit and can be tested via the following circuit. This circuit will also test ZENER DIODES and LEDs.

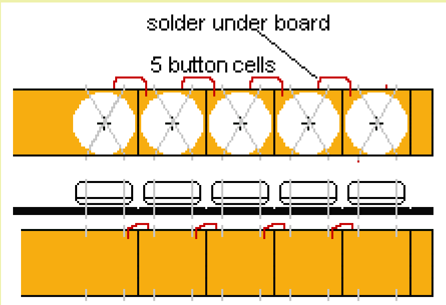


TRANSISTOR and ZENER TESTER CIRCUIT

The circuit is a **flyback oscillator**. This type of oscillator energises an inductor then turns off very quickly and the magnetic field (flux) produced by the inductor collapses and produces a very high voltage in the opposite direction. The maximum voltage produced by the circuit depends on the "maximum voltage capability" of the transistor.
The voltage produced by the inductor is over 120v but the transistor will zener at a voltage lower than this and thus the output voltage will be determined by the characteristic of the transistor.
A diode on the output of the inductor passes this high-voltage-spike to a 1u electrolytic, which stores the energy and provides a high voltage output.
The circuit will test transistors up to 120v and zeners up to the voltage produced by the transistor.
The project is built on a strip of PC board cut into lands with a file or saw. The following diagrams shows the parts placement and connecting the 5 button cells to the board.
The project can be built in an evening and added to your TEST EQUIPMENT.



ZENER DIODE TESTER COMPONENTS LAYOUT



Underside of PC board

TESTING A TRANSISTOR

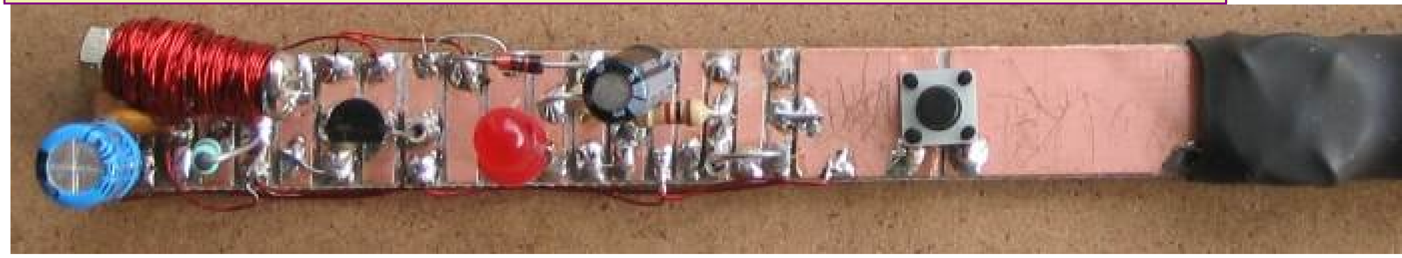
When testing a transistor, fit it into the pins marked C B E. If you have a LED connected to the LED terminals, it will glow. If you remove the LED and measure the voltage across the 1u electrolytic, it will provide the maximum working voltage for the transistor.

TESTING A ZENER

When testing a zener, place it in the pins provided. If the zener is around the wrong way, the voltage across it will be less than 1v.
When it is placed correctly, you can read the zener voltage with a high impedance multimeter such as a digital meter.

TESTING A LED

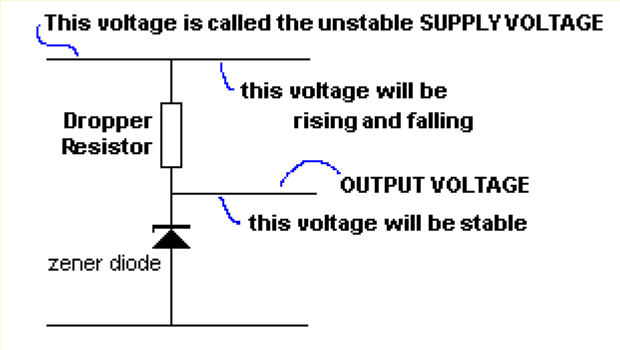
When testing a LED, fit it into the pins for the LED with the cathode lead (the shorter lead) to the left. It will glow very dim because the dropper resistor is very high and only allows 4 - 6mA to flow.
This will give you a good idea of the relative brightness of a LED when compared to others in a batch.



THE TRANSISTOR & ZENER REGULATOR

A transistor can be used to amplify the characteristics of a zener. You can also say the transistor is a **BUFFER** or **EMITTER-FOLLOWER**. It is another example of the transistor as an **AMPLIFIER** - a **DC AMPLIFIER** - indicating it amplifies the "steady-state" conditions provided by a zener diode.
We will start with the simple **Zener Regulator** circuit, then add the transistor amplifier. After that, we will remove the zener and add another transistor to improve the smoothness of the output waveform.

A simple zener regulator circuit is very wasteful however it is the basis for creating a stable output voltage from a voltage that may be rising and falling a considerable amount.
The following circuit shows a simple zener regulator:

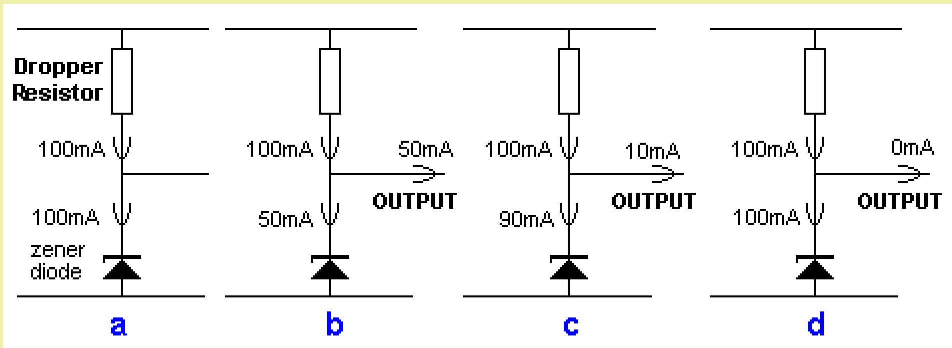


A Zener Regulator Circuit

A **Zener Regulator Circuit** consists of a zener and a resistor. The resistor is called a **Dropper Resistor** and it is designed to limit the **CURRENT**. It is not designed to limit the VOLTAGE. The zener diode performs the task of limiting or SETTING the voltage on the output.
The current through the Dropper Resistor will be shared between the zener diode and the LOAD (on the output of the circuit). These two items may or may not share the current equally, and the amount of share will depend on the value of the LOAD. We can also say the Dropper Resistor is a **CURRENT LIMITER**. If is is not included, a 12v zener connected to a 15v supply would draw (or take) a very high current and "burn out."

Here's the important fact about the current-sharing between the zener and load:
Suppose the SUPPLY VOLTAGE is fixed.
Here's an example of how the zener diode works:
Suppose we select a resistor so that 100mA flows through the zener when no load is present. Fig (a)

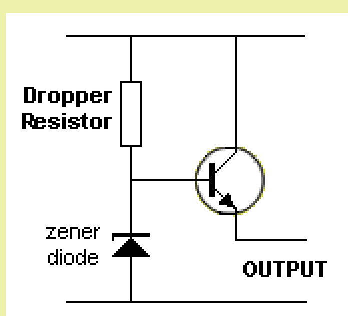
When the load takes 50mA, the zener takes 50mA. Fig (b)
When the load takes 90mA, the zener takes 10mA. Fig (c)
When the load takes 100mA the zener takes 0mA.   Fig (d)



Current-sharing between the zener and output

Up to this point the circuit works perfectly. Even though the zener takes 0mA, the circuit is operating perfectly and the output is smooth. If the load tries to take 101mA, the output voltage will DROP.
This is point at which the circuit is said to FALL OUT OF REGULATION.
The load (the OUTPUT) can take more the 102mA and the output voltage will drop further, but we are interested in the range where the output voltage is STABLE (fixed).
In this example, the current though the Dropper Resistor is ALWAYS 100mA. The current is then split (or shared) between the zener diode and the LOAD.
This feature is always the case with a zener diode regulator.
100mA is always flowing though the Dropper Resistor and if the load is taking only 10mA, this type of regulator is very inefficient.
When the supply rises, the current though the Dropper Resistor will increase. When the Supply falls, the current through the Dropper Resistor will decrease. During this time the output voltage of the circuit will remain constant providing the current though the zener is always at least a few mA and the maximum value does not allow the zener to get too hot. If the zener gets too hot it may fail.

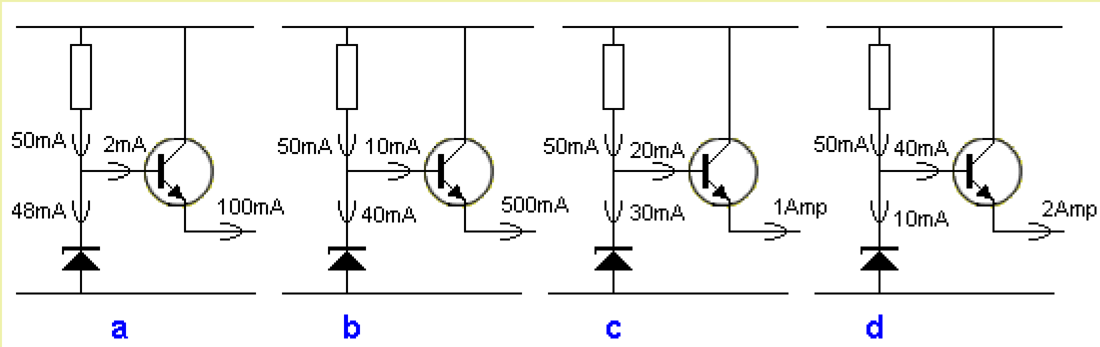
The efficiency of the **ZENER REGULATOR** can be improved by adding a transistor. The transistor is an amplifier. A **CURRENT AMPLIFIER**. (also called a DC amplifier)
This type of circuit is sometimes called a **SUPER ZENER or AMPLIFIED ZENER**. The transistor is connected as an emitter-follower as shown in the following diagram:



An emitter-follower transistor

If the transistor has an amplification-factor of 50, it will require 2mA (into the base) for each 100mA delivered to the output.
This means our Zener Regulator only needs to deliver 2mA and the output can deliver 100mA. The

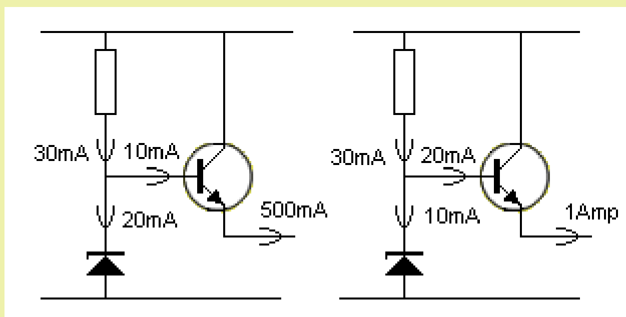
emitter-follower transistor must be a POWER TRANSISTOR.
Here are some examples from 100mA to 2Amp:



The transistor has a gain of 50

In the circuits above, the output current can range from 100mA to 2Amp. The zener will pass 48mA when the load is 100mA and drop to 10mA when the load is 2Amp.

If the output requirement is only from 500mA to 1Amp, the value of the dropper resistor can be changed so the zener takes 20mA when 500mA output current is required and 10mA when 1 amp is required.



When designing this type of circuit, the zener is allowed to take 10mA when the maximum current is required. The 10mA is about the minimum current for a 12v (300mW to 500mW) zener to keep it in conduction. The actual minimum value depends on the wattage of the zener and also its voltage. You will need to look at the specification sheet for the zener you are using.

The term "keep it in conduction" means this: Suppose we have a 12v zener and dropper resistor connected in series. As the voltage (the SUPPLY VOLTAGE) on the combination is reduced, the current through the zener reduces. If you supply the combination with 11.5v, the zener will "fall out of conduction" and it will appear like a very high value resistor or even an infinite resistance.
In the transistor / zener regulator circuit above, if the current taken by the load increases above 1Amp, the current into the base increases and when it reaches 30mA, the zener receives NO CURRENT.
Any further increase in current by the load causes more current to flow through the Dropper Resistor and the voltage across this resistor will increase. This will lower the voltage on the base and also lower the voltage on the emitter. At this point the zener has dropped out of regulation.

If the transistor has a gain of 50, the maximum output current is divided by 50 and this gives the base current of 20mA.
Add 20mA to 10mA to obtain the current through the Dropper Resistor.

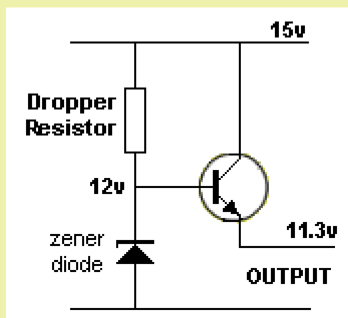
The value of resistance for the Dropper Resistor is obtained by the formula:

$$R = \frac{\text{voltage of supply - voltage of zener}}{\text{current through Dropper Resistor}}$$

Suppose the supply is 15v and the zener is 12v . The value of the Dropper Resistor is:

$$R = \frac{15v - 12v}{0.03\ \text{Amp}}$$
$$= \frac{3}{0.03} = 100R$$

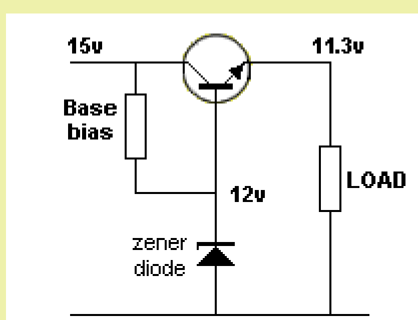
The output voltage is 0.7v less than the voltage of the zener.
The following diagram shows an example of the voltages on a typical regulator circuit:



The voltages on the regulator circuit

SUMMARY

A power transistor can be used to amplify the characteristics of a zener. That's what the circuit above is doing.
The circuit is sometimes drawn as shown in the following diagram. It is more difficult to see exactly how the circuit is operating, but this is how it is drawn in many projects. By drawing the circuit as shown above, you can see the voltages on each section of the circuit and you can't make a mistake. One "circuit engineer" said the output was 1.2v above the input voltage. But when you draw the circuit as suggested, you can clearly see this is not possible.
That's why the layout of the circuit is MOST IMPORTANT.



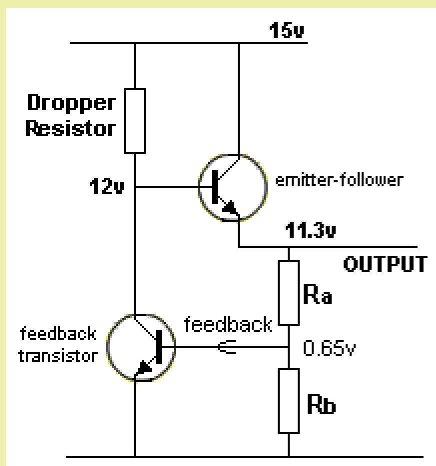
The regulator circuit re-drawn

IMPROVING THE SMOOTHNESS OF THE OUTPUT

The quality of the output (meaning the smoothness of the output) of a regulator - also called the smoothness of a POWER SUPPLY - can be improved by adding a transistor that detects any increase or decrease in the the output voltage and produces an opposing signal to counteract the rise or fall. The end result is very smooth DC.
The action of this transistor is called **NEGATIVE FEEDBACK**.
In the regulator circuit above (and the circuit with the transistor amplifier), the output is not being monitored and if the zener is noisy, (in other words it breaks down in an irregular mode and creates ripple) there is no feature to detect the changes, and reduce them.

The following circuit uses a transistor to detect the output voltage and provide a feedback signal (feedback voltage) that will eliminate the ripple. It is called a **FEEDBACK SIGNAL** or simply **FEEDBACK**.
The zener diode can be removed and two resistors used to monitor the output voltage with the voltage at their join being passed to the feedback transistor.
The base-emitter voltage of the transistor replaces the zener diode as a "reference" and the transistor turns into a zener diode with the "zener reference" appearing between the collector and emitter.

The following circuit shows the feedback transistor replaces the zener diode in the circuit above and two VOLTAGE DIVIDER resistors on the output are connected to the base of the feedback transistor.



When the circuit turns ON, the output voltage rises until the voltage at the join of the resistors reaches 0.65v. The feedback transistor starts to turn ON and prevents the base of the emitter-follower transistor rising above 12v. This creates an output voltage of 11.3v.
Any reduction in the output voltage will turn off the feedback transistor a very small amount and it will allow the voltage on the base of the emitter-follower transistor to rise and this will increases the output voltage.
The feedback transistor is also called an **ELECTRONIC FILTER**.
It has an effect equal to the gain of the transistor (approx 100) on smoothing the output.

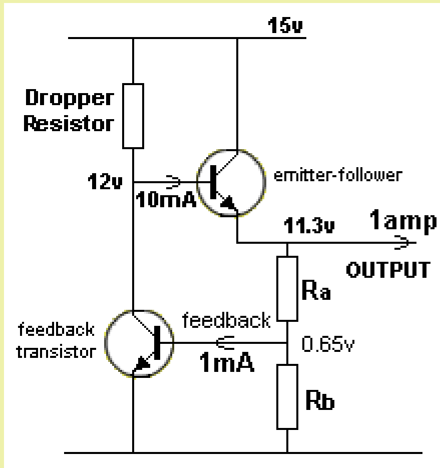
HOW DO YOU WORK OUT THE RESISTOR VALUES?

For the resistor values for the following circuit, we start with Ra and Rb.
The output current is 1amp and the transistor can handle more than 2 amps, so the gain at 1amp is 100.
The feedback transistor also has a gain of 100, but this is not important for these calculations.
Starting with Ra and Rb, we allow 10mA to flow though this voltage divider so the stability of the circuit is very high.

The resistance of Rb = 0.65/.009 = 72 ohms.
The resistance of Ra = 10.65/0.01 = 1.065k

The resistance of the dropper resistor = 3/0.01 = 300 ohms

The circuit turns on via the 300 ohm dropper resistor pulling the base UP. As the output voltage rises, a point is reached where the voltage into the feedback transistor reaches 0.65v and the transistor turn ON. **It turns into a resistor** and the join of this "resistor" and the Dropper Resistor create a voltage of exactly 12v. At this point the circuit becomes stable.



Ra and Rb can be any values providing the ratio is 72:1065. For instance, the values can be 144:2130 or 108:1597 (where the values are increased by 50%).
The value of the **Dropper Resistor** can be any value **less than** 300R and although this will theoretically allow more current to enter the base of the emitter-follower transistor, the transistor will not take any more current than it requires to create the necessary collector-emitter current (and thus the exact voltage of 12v at the collector).

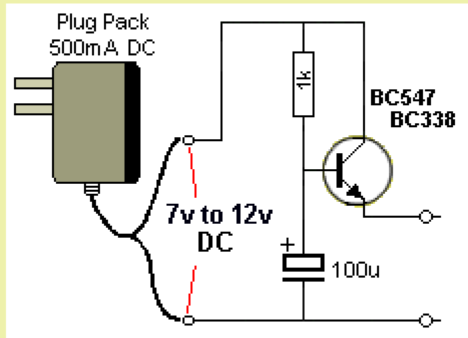
TRANSISTOR GAIN

As the current through a transistor increases, the gain of the transistor decreases. This means a transistor may have a gain of 100 when a small current is flowing thorough the collector-emitter circuit, but as the current increases to say say 50% (of the maximum allowed for the device), the gain may decrease to 50.
As the current increases to a maximum, the gain may decrease to 20.
All these values are variable and we cannot specify any exact values, so you have to remember to takes these facts into account when designing a circuit.
That's why a transistor with a maximum collector current of 4 amps is chosen for a circuit requiring 1 amp. You are not over-stressing the transistor and it will provide a gain of about 100.

THE ELECTRONIC FILTER

Here is a simple circuit to reduce the ripple from a power supply by a factor of about 100. This means a 20mV ripple will be 0.2uV and will not be noticed. This is important when you are powering an FM bug from a plug pack. The background hum is annoying and very difficult to remove with electrolytics. This circuit is the answer. The 1k and 100u form a filter that makes the 100u **one hundred times** more effective than if placed directly on the supply-line. The transistor detects the voltage on the base and also detects the very small ripple.
As current is taken by the load, about 100th of this current is required by the base and if the load current is 100mA, the current into the base will be 1mA and one volt will be dropped across the 1k resistor.

The circuit is suitable for up to 100mA. A power transistor can be used, but the 1k will have to be reduced to 220R for 500mA output. The output of the circuit is about 2v less than the output of the plug pack.
By reducing the 1k or adding a zener across the electro, the voltage will remain much more constant (fixed).



An ELECTRONIC FILTER

THE ELECTROLYTIC AS A FILTER

The circuit above shows an electrolytic used to remove the ripple from a power supply.
1. How does the electrolytic reduce the ripple?
2. Why do you need a larger capacity electrolytic for a higher current?

1. The electrolytic is just like a rechargeable battery.
When the voltage is higher than normal, the electrolytic gets charged and this puts an additional load on the supply. Some of the extra voltage (as well as the current being delivered by the supply-voltage) is passed to the electrolytic as energy and the supply voltage is reduced slightly.
When the supply-voltage drops, the voltage contained in the electrolytic is slightly higher than the supply and it delivers energy. This prevents the supply-voltage dipping too much.
You can see the electrolytic is receiving and delivering only a very small amount of its stored energy and that's why its value must be very large (about 1,000u for each amp delivered by the power supply). This is because the electrolytic has to have a large ability to store a lot of energy when the voltage rise and falls only a very small amount.
2. When the current is a large value (say 1 amp), the energy contained in a few millivolts and a current of 1 amp, is a very large and thus a high capacity electrolytic is needed.

When an electrolytic is placed across a power rail, it smoothes the voltage by BRUTE FORCE. A large electrolytic will produce more smoothing.
But when the electrolytic is connected to the supply via a resistor, the electrolytic will take time to charge when the voltage rises and time to discharge when the voltage fall.
This means the ripple on the electro will be much less than the ripple on the power rail.
Depending on the value of the resistor and electro, it may be 1/100th of the ripple on the supply.
The transistor detects this improved voltage and allows a high current to pass to the load.

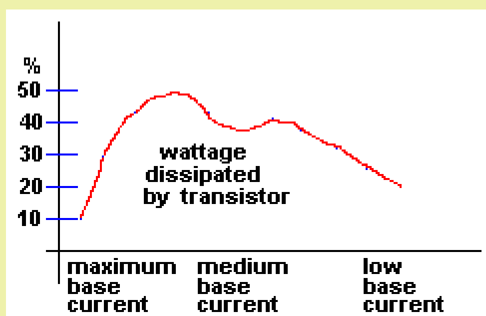
THE TRANSISTOR AS A LOAD

This might seem an unusual topic but many circuits use a transistor as a LOAD or VARIABLE LOAD or partial load (in conjunction with a LOAD RESISTOR) to dissipate (remove - take away) power - to prevent another item (such as battery) being overcharged or a delicate device getting too hot.
We are talking about wasting energy or losing energy in the form of heat to prevent another item in a circuit getting too hot.
A power transistor such as 2N 3055 is ideal for this purpose however there are smaller power transistors for smaller losses.
We use the gain (amplification factor) of the transistor to provide this feature and by controlling the base

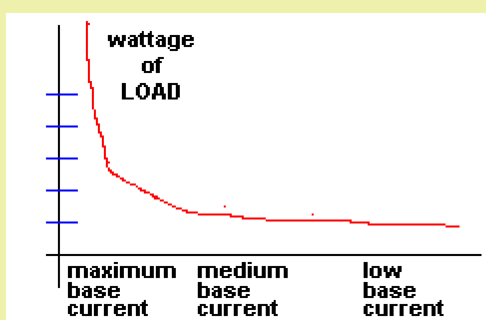
current, the current though the collector-emitter terminals can be adjusted. In most cases the transistor is in series with a LOAD RESISTOR and the two items can be adjusted to remove unwanted energy.
In addition, the percentage dissipated by the transistor compared to the load resistor depends on the base current of the transistor.
This is quite a complex topic as the losses can be adjusted to any percentage, irrespective of the supply voltage.

This is sometimes called an **ELECTRONIC LOAD** or **ACTIVE LOAD** because the effectiveness in dissipating heat can be controlled by current entering the base of the transistor.
A POWER RESISTOR (by itself) is called A DUMMY LOAD or STATIC LOAD. It's dissipation is fixed (providing the voltage of the supply is fixed).
Our discussion introduces a variable dissipation, controlled by the base current of a transistor.
This is another example of a transistor being used as an amplifier. The current into the base is amplified by the transistor to produce a current through the collector-emitter leads.
This current also flows through a LOAD RESISTOR and the resistor increases in temperature.
The loss in the transistor and resistor is calculated in terms of watts and when this is extended over a period of time, the result is energy - watt-hours. This energy is given off as heat instead of raising the temperature of a critical component in a circuit.

The following diagram shows the heat dissipated in the transistor when maximum, medium and low current flows into the base of the transistor:



When maximum base current is supplied to the transistor, it is turned ON fully and only about 10% of the total wattage is lost in the transistor. This means the total wattage of the load can be very high.
As the current is reduced, the wattage dissipated in the transistor increases to about 50%, then drops off.
The following diagram shows a large wattage will be dissipated in the resistor (and very little via the transistor) when maximum current is supplied to the base of the transistor, but as the base current is reduced, the size of the load must also be reduced because more of the load is dissipated in the transistor (and the transistor is the limiting factor).



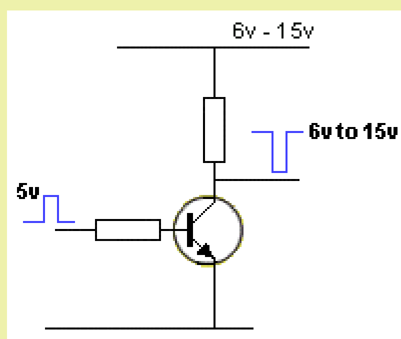
It is impossible to work out the "load sharing" between the transistor and resistor for any given base current because transistors from different batches have considerably different characteristics.

The diagrams we have provided show percentages but not the base current required to create the load sharing.
Even simulation software will produce false data as the actual characteristics of the transistor you are using will be unknown.
Rather than spending time on trying to work out the probable results via a software package, it is much easier to build the circuit and apply current to the base.
As you apply current into the base, you can monitor the current through the load via an ammeter and provided the transistor is correctly heatsinked, it will not overheat.
A 2N3055 will dissipate 115 watts using a very large heatsink. This gives a starting-point for the maximum wattage for the system.
When the transistor is turned on so it dissipates the same wattage as the resistor, the total losses for the system can be as high as 230 watts, but when the transistor is fully turned on, the system can handle about 1,0000 watts.
However the transistor must change very quickly from a state where it is not turned to a fully turned-on-state. (If not, the transistor will be damaged very quickly if it becomes partially turned on.)
In the fully-turned-ON state, the transistor is fully saturated and is dissipating only about 10% of the total load and the resistor is dissipating about 90%.

These are all points you need to know, when designing an **ACTIVE LOAD**.

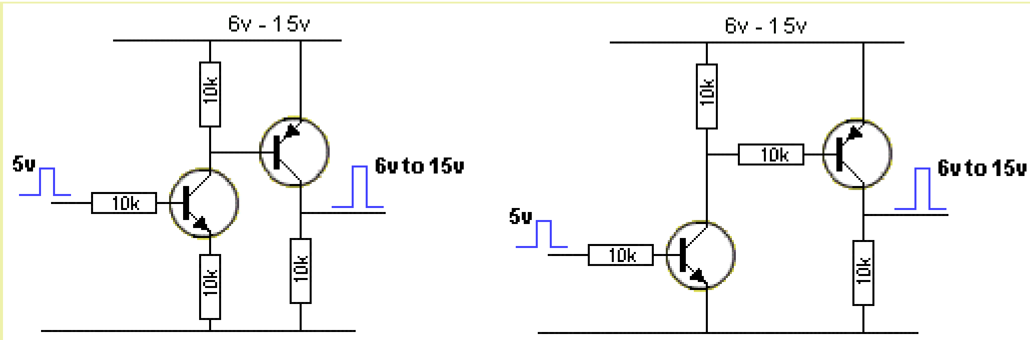
THE TRANSISTOR AS AN INVERTER

A transistor can be configured as an inverter - to change a signal (that moves from LOW to HIGH) into a signal that changes from HIGH to LOW.
This type of circuit can be used to transform a 0-5v signal into a 0-9v signal. This is called **VOLTAGE SHIFTING** or **LEVEL SHIFTING**. In this case, a LOW to HIGH (0-5v) signal is converted to a "HIGH to LOW" (0-9v) signal. The output changes when the base sees a voltage between 0.55v and 0.7v. The remaining input voltage is dropped across the base resistor. The output voltage will be initially HIGH and go LOW as soon as the input voltage reaches about 0.7v.



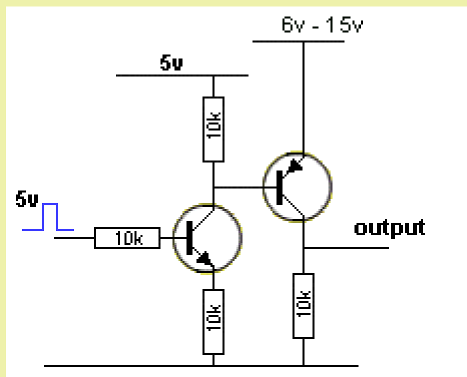
5v to 15v Inverter

A non-inversion circuit is shown in the following diagrams:



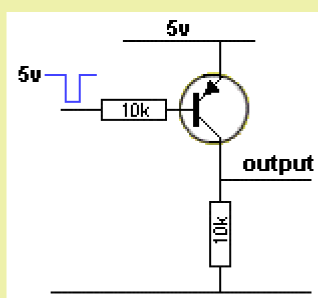
5v to 15v Non-Inverter

The following circuit does not work because the second transistor is never turned off. Both transistors MUST be connected to the high voltage rail.



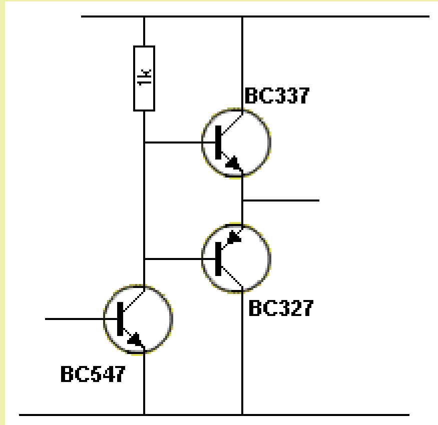
This circuit does not work

The following circuit converts a signal that starts as **5v HIGH** and goes **LOW**. During this signal transition, the output start with a **LOW** value and goes **HIGH**.



5v to 0v Inverter that produces 0v to 5v Output

The following circuit is a Push-Pull Inverter:



Push-Pull Inverter

All the circuits above convert an analogue signal or A DIGITAL SIGNAL into a digital signal. This is due to the gain of the transistor. In other words the output does not respond in a linear manner, (to the input voltage). The output changes when the input moves from a voltage of about 0.55v to about 0.7v. Input voltages below 0.55v have no effect and voltage above 0.7v do not affect the circuit as the circuit has already changed state.
One other characteristic of the circuit is this: It speeds up the waveform and removes noise from a noisy signal.

ADDING A TRANSFORMER

One of the most complex electrical/electronic components is the TRANSFORMER. It is the simplest component and yet it produces the most complex effects. A transformer is simply a coil of wire placed near another coil of wire. The results and effects will amaze you.
There are so many different effects, we could write an eBook.
In fact we will write a chapter on the subject, but firstly we will cover 5 things:
1. A single coil of wire is not a transformer but an inductor.
Without going into any complex mathematics, here is a fact you should know:
When an inductor is connected to a battery, the current does **not** flow though the turns immediately, but a few microseconds or milliseconds later. This is called **CURRENT LAG**. Don't ask why, it's just a fact.
But the most amazing thing is this: When the voltage is removed, the inductor produces a HIGHER output voltage IN THE REVERSE DIRECTION.
If the coil is wound on a cardboard former, the core (the centre of the coil) is air and the voltage (the reverse voltage) produced, may be twice the supply voltage. But if the core is steel or other magnetic material such as iron (stalloy) or ferrite (a special type of iron) the reverse voltage may be 100 times HIGHER or even 1,000 times HIGHER.
That's why a simple coil of wire is one of the most amazing things.
We can control the magnitude of this reverse voltage by adjusting the frequency and/or the speed at which we turn the voltage OFF.
Even though the inductor is not called a transformer, we are "transforming" a low voltage into a high voltage.
We are not getting "something for nothing." **Conservation of energy still applies**. We are transforming a low voltage at high current into a high voltage at low current. The watts **IN** equals the watts **OUT**.
When we add another winding, the two coils become a TRANSFORMER.
The first winding is called the **PRIMARY** and the second winding is called the **SECONDARY**.
We drive a transformer in a slightly different way to an inductor.
We deliver a rising and falling voltage to it slowly. This is called an AC delivery and although the letters "**AC**" mean Alternating Current, we really mean Alternating Voltage.
When we deliver a slowly rising and falling voltage, the primary does not produce the high reverse voltage

discussed above but it does produce a **reverse voltage** that can be as high as 99.99% of the applied voltage. But this is getting away from the point we want to cover.
The secondary winding produces an exact copy of the voltage flowing into the primary and if you measure it on a piece of test equipment, it will follow the primary exactly (but slightly delayed). If you reverse the leads to the test equipment, the results will be a "mirror image." That's how we get a reverse voltage out of the transformer.
Here's the next valuable fact: The voltage from the secondary will be higher if the secondary has more turns or lower if the secondary has fewer turns than the primary.
If it has more turns, the transformer is called a **STEP-UP** transformer and if it has less turns the transformer is called a **STEP-DOWN** transformer.
Here's our last amazing fact:
If the secondary has less turns, the current from the secondary can be higher than the current in the primary. But if the secondary has more turns, the current from the secondary will be less than the current in the primary.
With all these facts and capabilities, we can do incredible things with a transformer.
We forgot to mention one of the most beneficial uses for a transformer. The voltage on the primary is totally isolated from the secondary. In other words, the primary may have 110v or 230v on it and the secondary may have 12v. You can touch either lead of the 12v winding and any metal pipe and not get a shock. The transformer provides total isolation. But if you touch either end of the primary winding and a metal pipe you will be killed instantly.
That's one of the main uses for a transformer - to provide isolation from the "mains." The energy passes from the primary winding to the secondary via **magnetic flux** and the two windings are ISOLATED and INSULATED from each other.
A transformer can be smaller that a grain of rice to the size of a house and there are millions of different types. That's why they are so complex.

As soon as the eBook article is written, it will be included HERE.

A transformer is a complex item. It takes up a lot of space on a PC board and is expensive to make.
It is not added without a reason and a lot of thought.
Here are 8 reasons why a transformer is included in a project
1. To produce a voltage higher than the supply,
2. To produce a very low voltage,
3. To produce a high current,
4. To produce a sinewave wave,
5. To mix two different signals or frequencies,
6. To produce a feedback signal,
7. To produce a number of different, isolated voltages (and/or current),
8. To produce isolation. And many other reasons.

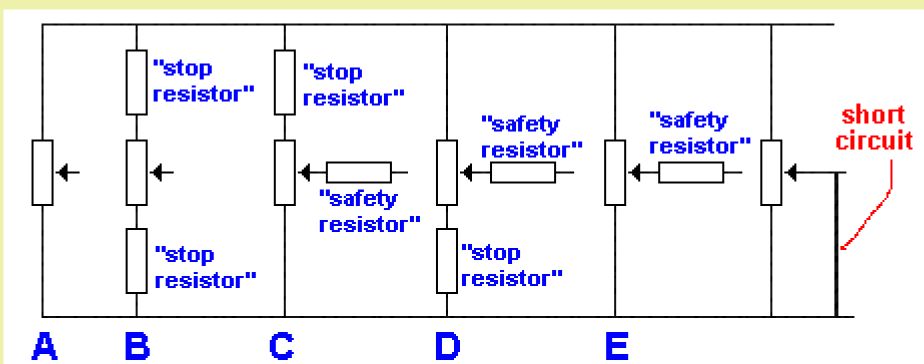
Driving a transformer is not like delivering current to a resistive load.
The primary winding of a transformer has a very small resistance but when it is delivered an increasing voltage, the magnetic flux (produced by the voltage) creates a voltage in the opposite direction that cuts the turns of the winding and this voltage opposes the incoming voltage.
This effectively makes the winding appear to be a higher resistance. When a transformer is delivering energy via the secondary winding, the "back-voltage" produced by the magnetic flux will be less and the input current (via the primary) will be higher.
A transformer is designed to receive an increasing and decreasing voltage. During this time it can deliver energy to the secondary.
But when the voltage rises and remains HIGH, the opposing voltage produced by the expanding magnetic flux ceases and input current increases considerably.

DESIGNING A TRANSFORMER

Designing a transformer is very difficult and complex. The easy approach is to buy a product that contains a circuit similar to your requirement and use the transformer.
It is very difficult to take a transformer apart as the laminations or the ferrite core is dipped or glued or sealed so the windings do not move.
In some cases you can buy laminations or ferrite cores (called pot cores) but there are many different types of materials and unless you know the composition of the material, the resulting transformer can be as low as 10% successful.
The other problem with taking a transformer apart is this:
Many transformers have an air-gap in the magnetic circuit to "remove" or "use-up" the magnetic flux created by the DC component of the input current.
If this air-gap is not maintained in its exact thickness, the new transformer will not be identical in performance to the original.
A transformer without an air gap must have "lapped surfaces" so the two halves of the core touch each other.
All these technicalities will be covered in the eBook.

THE POTENTIOMETER

A potentiometer is simply a resistor with the resistance-material exposed to a wiper.
The resistance-material is called a TRACK and it can be straight or curved. When the track is curved, we generally call it a "pot" (abbreviation for potentiometer) and the pot is rotated to increase or decrease the resistance. When the track is straight we call it a 10-turn pot. And a screw is available on the end of the pot. Straight tracks are also available in pots called SLIDERS. All pot have the same symbol.
In most cases a pot is connected to a circuit with a resistor on one end or on the centre terminal (the "wiper") as shown in the following diagrams:



STOP RESISTOR and SAFETY RESISTOR

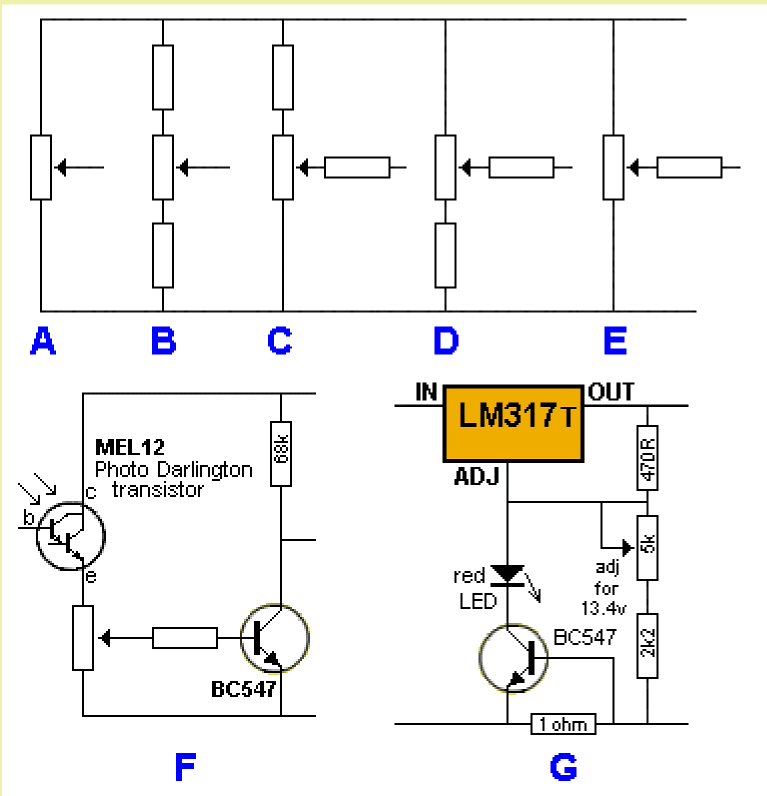
A resistor added to the top or bottom of the pot is called a **stop resistor**. It stops the pot reaching full rail voltage or 0v. A **safety resistor** is added to the wiper so the pot is not damaged when turned fully clockwise and the resistance of the output is low.
Fig A above shows a pot with no external resistors. The voltage on the wiper can be as high as rail voltage or as low as 0v.
Fig B shows a pot with a resistor to positive rail and one to 0v rail. The voltage on the wiper will not be as high as rail voltage or as low as 0v. By selecting a pot with a particular value and resistors for the top and bottom, maximum and minimum voltages can be set.
Fig C shows a pot with a top resistor. This sets a maximum voltage, while the minimum will be 0v.
Fig D shows a pot with a bottom resistor. This sets a minimum voltage, while the maximum will be rail voltage.
Fig E shows a pot with a resistor on the wiper. The allows the voltage on the wiper to be as high as rail voltage or as low as 0v. The resistor is called a "safety resistor." It prevents the pot being damaged if the output becomes shorted as shown in the last diagram.

If the pot in the last diagram is turned fully clockwise, the wiper will each rail voltage. If the wiper is connected to a low resistance, a high current will flow and damage the pot.
A "safety resistor" will reduce the high current.

There are three reasons why a pot is included in a circuit.
1. To "pick off" a voltage.
2. To deliver a current
3. To "pick off" an amplitude.

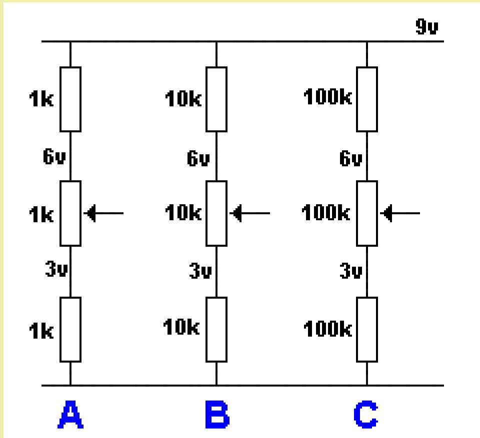
"PICKING OFF" A VOLTAGE

The following diagrams show a pot "picking off" a voltage. The pot values have not been shown because we are dealing with the concept of picking off a voltage.
In actual fact the pot will be delivering a current (via the wiper) to the circuit connected to the wiper, but to separate the functions of a pot, we have identified this function as PICKING OFF A VOLTAGE.
The main difference between **Picking Off A Voltage** and **Delivering A Current**, is the value of the pot.
The resistance of a pot for **Picking Off A Voltage** is generally a high value. The term "HIGH VALUE" is relative to the situation.
In Figs F and G you can see the SAFETY RESISTOR and STOP RESISTORS.
The wiper in figure F picks off a voltage from the pot. The pot is the load resistor for the MEL12 Photo Darlington Transistor and although it is delivering a small current to the base of the transistor, this current is very low and that's why we refer to the pot as "picking off a voltage."
The safety resistor in Fig F could be replaced with a stop resistor above the pot.
This change can be done in some circuits and you have to build the circuit to determine if the change can be made.

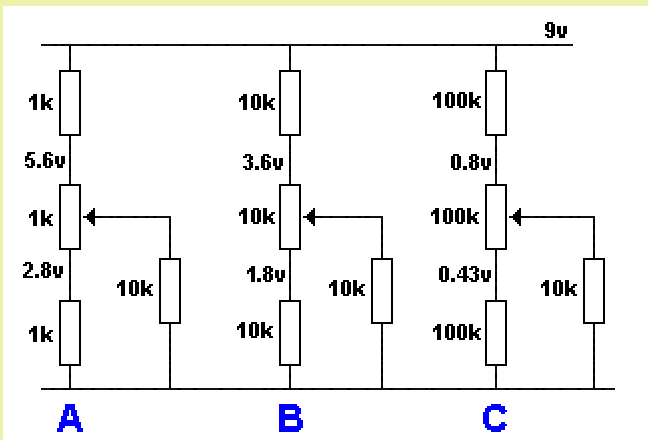


POT RESISTANCE

The resistance of a pot is selected from one of the following values: 100R, 500R, 1k, 5k, 10k, 50k 100k, 1M and 2M.
In most cases you will copy a circuit and use the same value for the pot.
Working out the value is quite a complex task.
Here are three different circuits. The voltage on the top and bottom of the pot is the same, but the value of the resistances is different.
The first circuit is classified as LOW IMPEDANCE. The second is MEDIUM IMPEDANCE and the third is HIGH IMPEDANCE.



The output from each pot will range from 3v to 6v. So, why different values of resistors?
The reason is to keep the current through the pot as low as possible.
The current through the resistors is WASTED CURRENT. If a project is battery operated, wasted current is a problem.
The resistance of the load on the wiper also determines the value of the pot.
Let's look at a 10k load connected to the wiper:



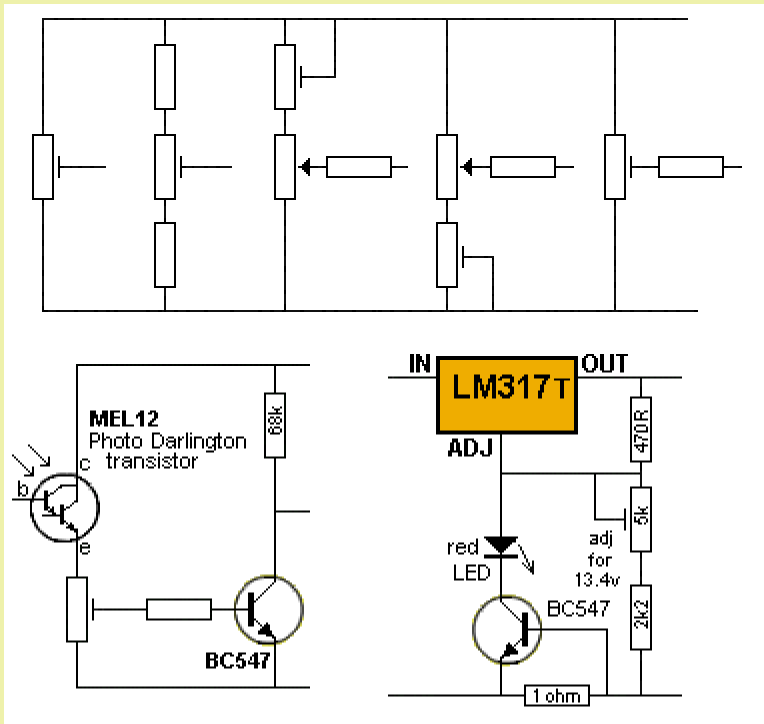
The voltage on the top and bottom of the pot changes when a load is added.
In circuit A, the voltage reduces a small amount as the 10k load has little effect on the low- value resistance of the pot and resistors.
In circuit B, the 10k load has a larger effect on the voltages.
In circuit C the 10k load has a major effect on the voltages.

This means it is necessary to choose values that are acceptable for minimum current through the pot as

well as creating the required voltage on the top of the pot.

TRIM POT

A trim pot is simply a pot without a shaft. It usually has a screw-driver slot and is adjusted once in the life of a circuit. It is usually small in size and can be any resistance value to suit the circuit.
It can be connected as the only pot in a circuit or used in conjunction with an ordinary pot to set a particular value or "setting."
It is identified in a circuit as follows:

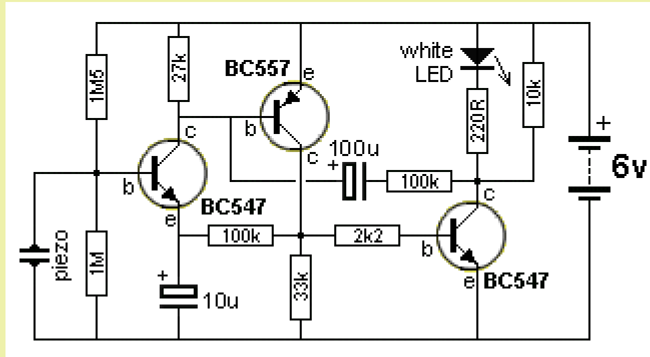


TRIM POTS can be used to trim the value of a POT

THE VOX - Voice Operated Switch

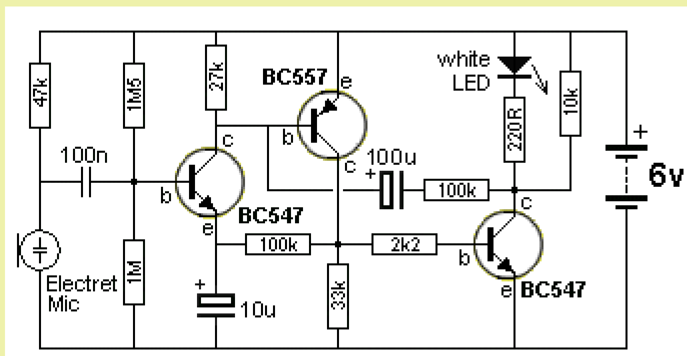
Basically, a VOX circuit is a very high gain amplifier that detects faint sounds and turns on a relay.
Here are a number of voice-operated (sound operated) circuits that turn on a relay or activate a device.
In general, a VOX circuit keeps the relay activated for a short time between sounds so the device remains constantly illuminated or activated.

The first circuit is a CLAP SWITCH. The LED illuminates for 15 seconds after the sound of a clap. For full details of the circuit see Fig 71acd.



CLAP SWITCH USING PIEZO DIAPHRAGM PICK-UP

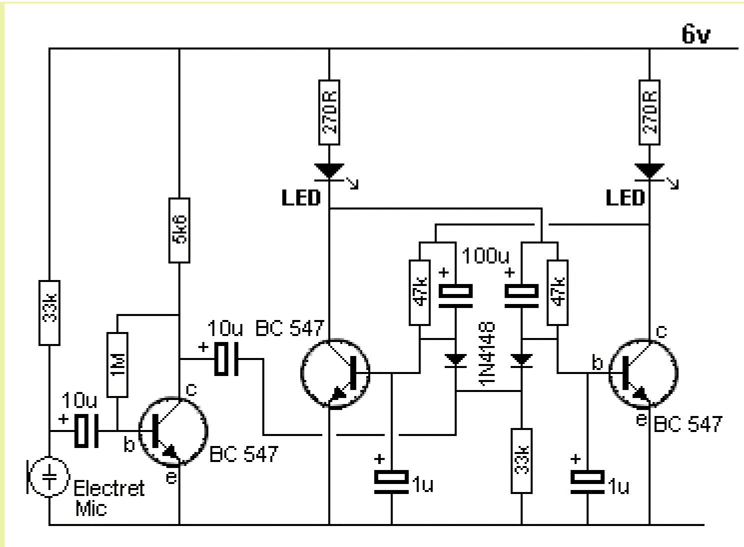
The circuit above takes about 20uA when "sitting around." That's because the piezo diaphragm does not require any current.
The same circuit can use an electret microphone for the input but the idle current rises to 200uA.



CLAP SWITCH USING ELECTRET MICROPHONE

Both circuits detect a clap but neither will detect faint noises or talking.
The circuits do not keep the LED illuminated constantly but only illuminate for 10 - 15 seconds and turn off for 10 - 15 seconds.

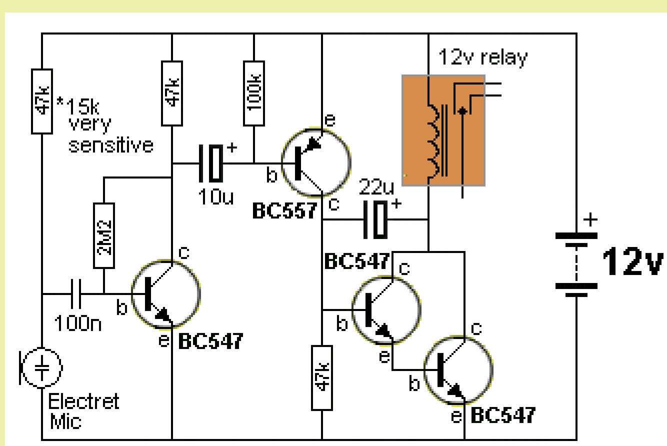
This circuit toggles the LEDs each time it detects a clap or tap or short whistle.



CLAP SWITCH TOGGLES THE 2 LEDS

The second 10u is charged via the 5k6 and 33k and when a sound is detected, the negative excursion of the waveform takes the positive end of the 10u towards the 0v rail. The negative end of the 10u will actually go below 0v and this will pull the two 1N4148 diodes so the anode ends will have near to zero volts on them.
As the voltage drops, the transistor in the bi-stable circuit that is turned on, will have 0.6v on the base while the transistor that is turned off, will have zero volts on the base. As the anodes of the two signal diode are brought lower, the transistor that is turned on, will begin to turn off and the other transistor will begin to turn on via its 100u and 47k. As it begins to turn on, the transistor that was originally turned on will get less "turn-on" from its 100u and 47k and thus the two switch over very quickly. The collector of the third transistor can be taken to a buffer transistor to operate a relay or other device.

The next VOX circuit activates a relay when audio is detected by the microphone. The relay is kept activated for 5 seconds after a silent period, by the 22u, to keep the relay fully activated during normal speech. The circuit takes 0.5mA when "sitting around."

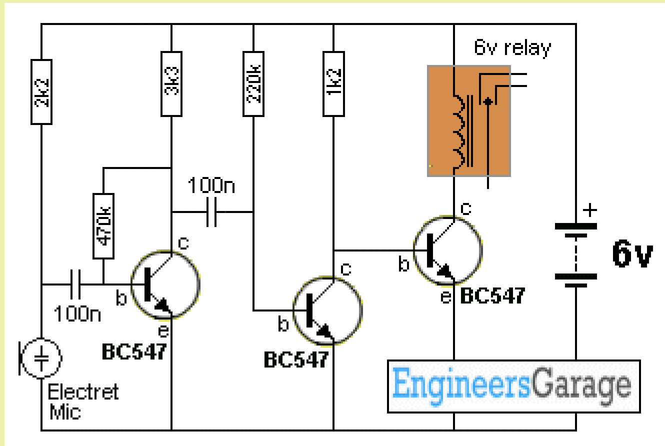


SENSITIVE VOX CIRCUIT

(Good design - circuit takes 0.5mA. Circuit keeps electro charged)

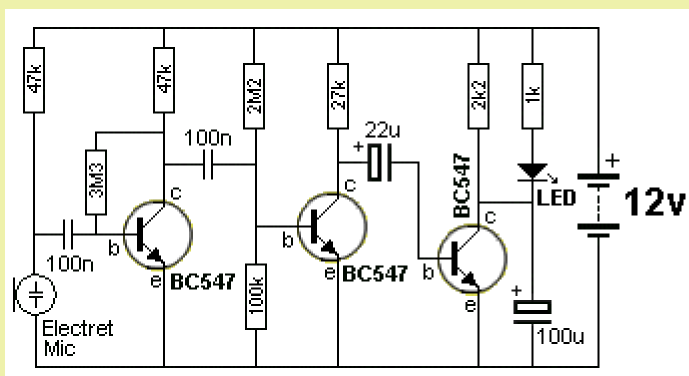
The circuit above is the best design as it uses the least number of components and drives a relay.

The next circuit comes from Engineers Garage website. It uses fewer components but takes more current (about 6mA) in the quiescent mode and does not have any delay to hold the relay ON:



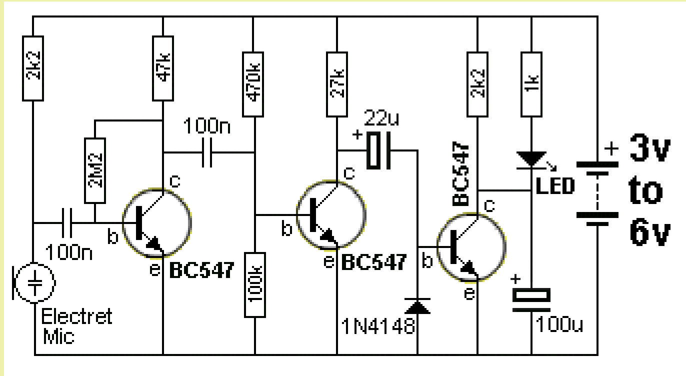
A 6v VOX CIRCUIT - no delay
(Not a good design - circuit takes 6mA)

The following two circuits detect audio and keep the LED illuminated for about 5 seconds. The delay is proved by the 100u capacitor on the output. The output is normally HIGH and goes LOW when audio is detected.
The LED shows the condition of the output. It is removed when you add the circuit to a project.
This circuit is the 12v version. Quiescent current (idle current) is 0.5mA.



12v VOX CIRCUIT
(Good design - circuit takes 0.5mA. Circuit keeps 100u discharged)

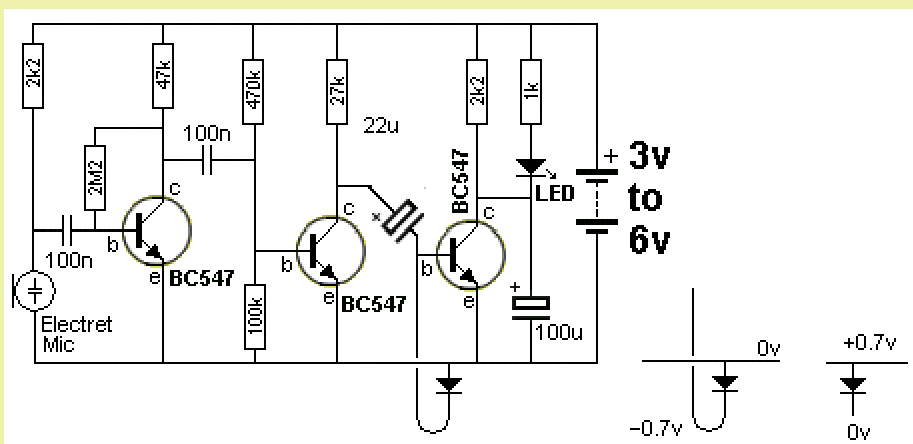
The following circuit is similar to the above. It is the 3v to 6v version. These two circuits detect the slightest whisper. Quiescent current (idle current) is 0.25mA.



3v to 6v VOX CIRCUIT

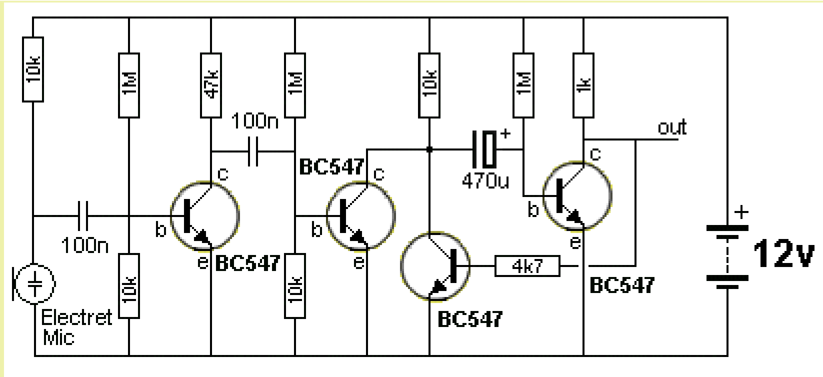
(Good design - circuit takes 0.25mA. Circuit keeps 100u discharged)

The addition of the diode in the 3v circuit is needed to discharge the 22u so that it produces its "full effect" to saturate the output transistor when required. It is not needed in the 12v circuit as the base-emitter junction of the output transistor "zeners" at about 5v and this helps to partially discharge the 22u. But when only 3v supply is present, the 22u has a maximum of only a few volt on it and none of its voltage will be removed. The output transistor is turned on when the middle transistor turns off. The 27k pulls the 22u high and if it is discharged, it pulls the base of the third transistor "up" and turns on the LED. During this time it gets charged slightly and this charging current flows via the base of the third transistor to turn it on. When the second transistor turns on, the 22u effectively "drops down" and the voltage across it (say 2v) will take the negative lead of the electro BELOW the 0v rail of the circuit. As soon as the negative lead is 0.7v below the 0v rail, the diode comes onto action.
As far as the diode is concerned, it sees a voltage of +0.7v on the anode lead with respect to the cathode lead and current will flow through it to discharge the electro. If the diode is removed, it would take a voltage of about -5v on the electro before it is discharged via the base-emitter junction of the transistor.



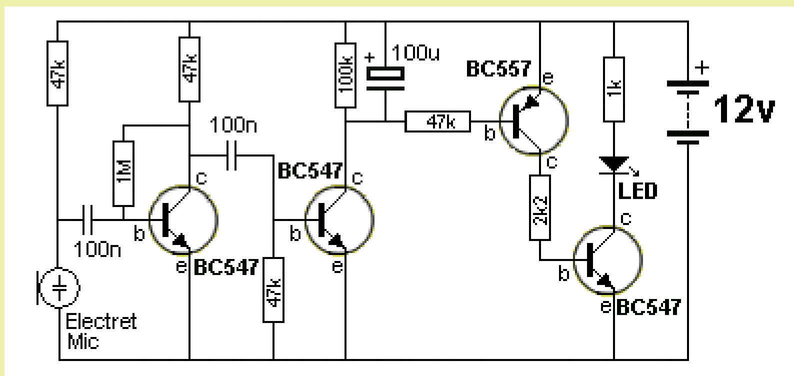
The 22u is discharged via the diode

The next circuit is designed by electroschematic.com. It is not a good design.
The circuit takes 14mA when sitting around and the 470u electro only needs to charge by about 0.5v before the circuit changes state. This uses only a fraction of the possible time delay for a 470u capacitor if the circuit is designed to charge it to a higher voltage before changing state.



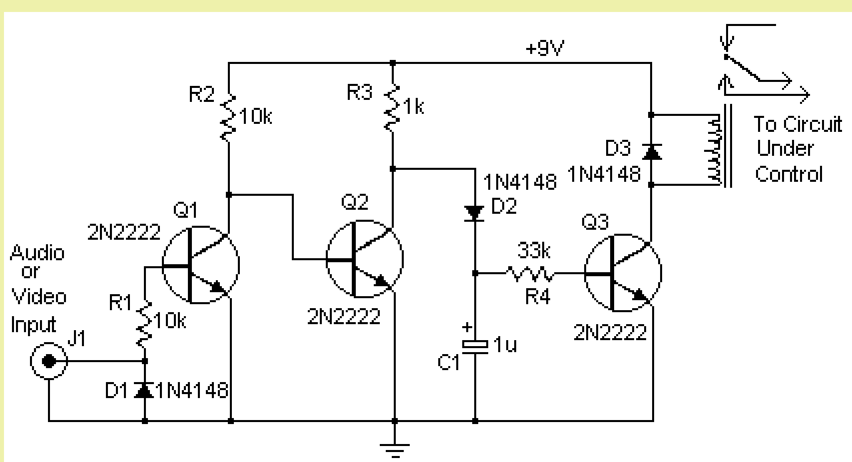
12v VOX CIRCUIT
(Not a good design - circuit takes 12mA)

Here is the circuit re-designed to take less quiescent current (0.5mA) and provide a longer delay with 100u electrolytic (20 seconds).



12v VOX CIRCUIT
(Good design - circuit takes 0.5mA.)

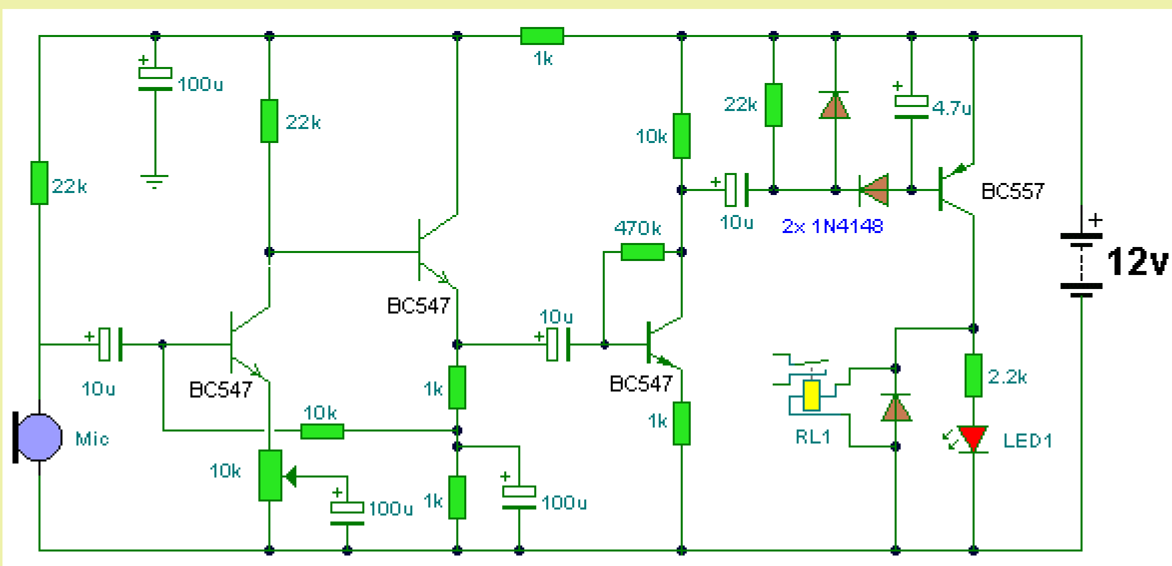
The next circuit can be Voice Operated or activated by a Video signal.



The circuit activates a relay when an audio or composite video signal is delivered to the input. This allows

you to use the tuner built into your VCR to turn on and off older TVs that are not equipped with a remote. It can also be used to activate surround-sound equipment, turn off room lights, turn on video game consoles, etc.
When power is applied, the first transistor is not turned on and the second transistor gets turned on via the 10k resistor. This prevents the third transistor turning ON and the relay is not energised.
When an audio or video signal is delivered to the input, the first transistor turns ON and this turns OFF the second transistor. The third transistor gets turned ON via the 1k and diode after the 1u gets charged a small amount.
When the input signal ceases, the first transistor turns OFF and this turns ON the second transistor. The third transistor no longer gets base current via the diode but the 1u holds a small amount of energy and this is delivered to the base to keep the relay active for a short period of time. After this the transistor turns OFF and the relay is de-energised.

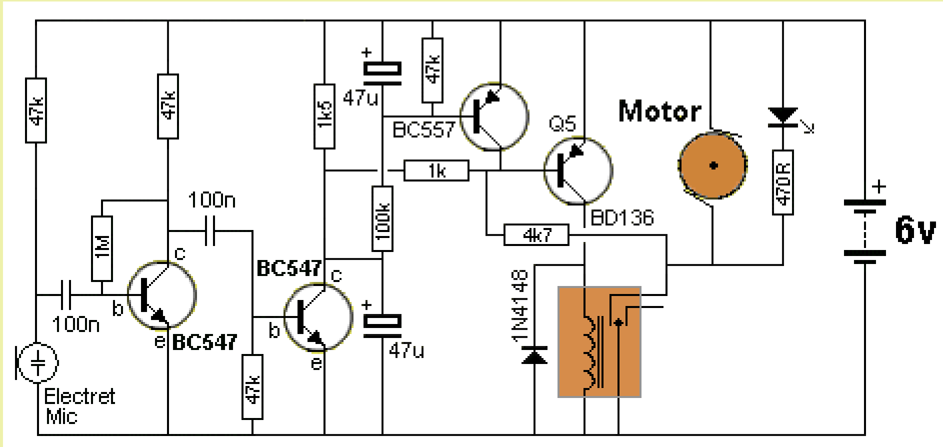
The next circuit is a little over-complex and could be improved.
Here are some suggestions:
1. The 10u from the microphone can be as low as 100n without any decrease in performance.
2. The 10k to the base of the first transistor should be a higher value to increase the input impedance of the first stage.
3. The 100u on the emitter of the first transistor can be replaced with a link.
4. The third transistor has a gain of 10. This can be increased by reducing the 1k.
5. The 22k and the two diodes can be removed and the circuit re-designed as shown above.
6. The 4u7 on the base of the 4th transistor is only charging to 0.7v. The delay section needs to be on the third transistor as shown above in the **12v VOX Circuit** and the fourth transistor should be a driver transistor.



This circuit can be improved

VOX TOGGLE

This clever circuit turns on a motor with a short whistle and turns the motor off with a long whistle. It's a toggle arrangement.

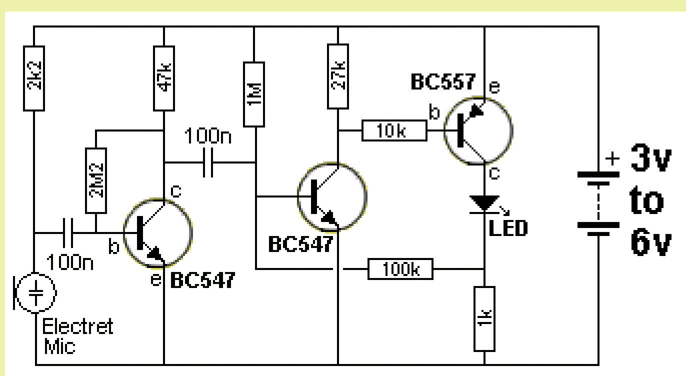


VOX TOGGLE CIRCUIT
Short tone = ON   Long tone = OFF

The circuit allows a whistle to turn an appliance ON and OFF by sending a short whistle to turn a circuit ON and a long whistle to turn a circuit OFF.
This is handy when you cannot see the result of your operation. A simple toggle operation is not suitable as you do not know the state of the output at the start of the operation.
By sending a long whistle, you definitely know the output will be OFF and you can then control the output remotely.
A short whistle is less than 0.25 sec and a long whistle can be any length longer than 1 second.
These times can be adjusted by changing the value of the components.
When a short whistle is received, the lower 47u discharges and pulls the base of the BD136 towards the 0v rail and turns the transistor ON. This activates the relay and the contacts take the 4k7 to the 0v rail to keep the transistor ON.
During this time the top 47u charges via the 100k but not enough voltage appears across it to turn on the BC557 transistor.
If the whistle appears for a long period of time, the top 47u charges and turns on the BC557 and the voltage between the emitter/collector terminals is less than 0.3v. This voltage is too low for the BD136 to remain on and it turns off.
When the whistle stops, the BC557 remains on for 1 second and then turns off.
The circuit is then ready to be activated again.

VOICE OPERATED LATCH

The following circuit latches a LED **ON** when sound is detected. It can be used to confirm a certain level of sound has been reached or exceeded during an event.



Sound makes LED stay ON

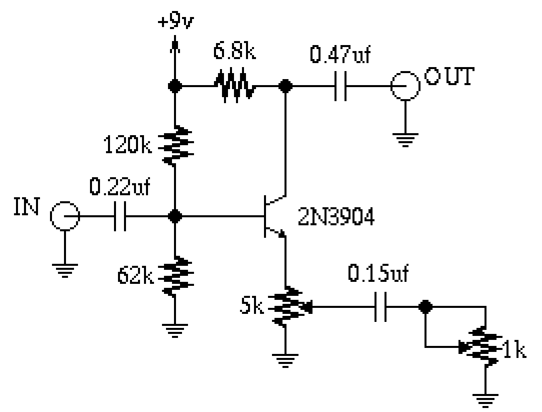
The electret mic and first transistor are active when the circuit is "waiting for a sound" and the 3rd and fourth transistors are biased OFF due to the 1M and 100k voltage-dividing resistors putting a voltage of between 0.27v and 0.54v on the base of the second transistor. This voltage is not high enough to turn the transistor ON. But the voltage helps to turn the circuit ON when audio is detected and makes it very sensitive.
You can see a poorly designed VOX latch circuit (Called Puff to OFF LED) in our Spot The Mistake eBook. These poorly-designed circuits show you how NOT to design a circuit and are just as informative as a good design.

ANALOGUE and DIGITAL mode

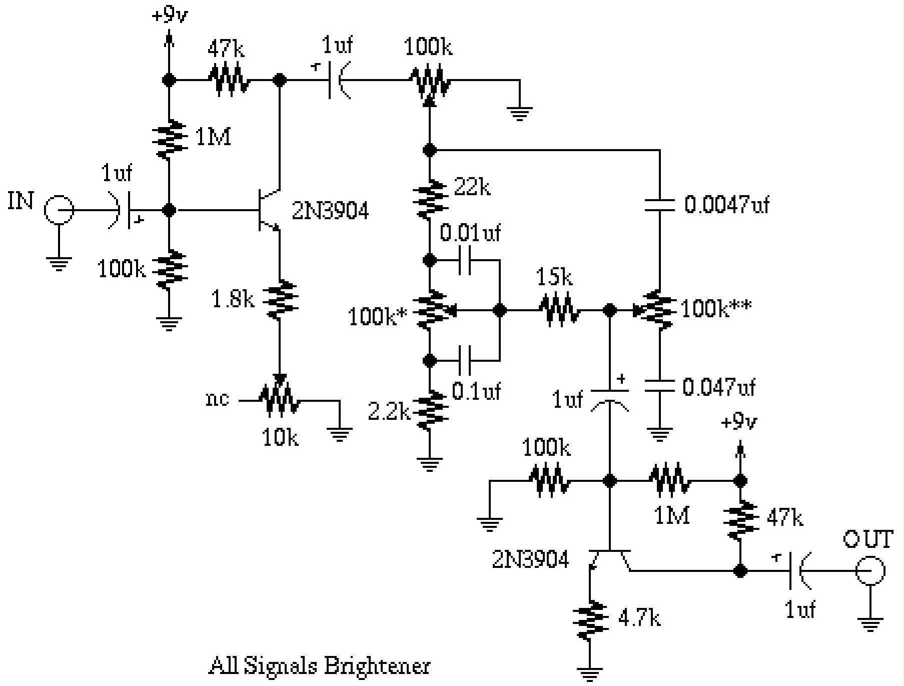
Now that we have covered more than 100 different circuits, you can see each transistor in a circuit is operating in either analogue or digital mode.
Sometimes it is easy to see the mode of operation.
If a transistor is not taking any current, then gets turned on (hard or fairly hard) it is operating in DIGITAL MODE.
If it is turned on with the collector at or about mid-rail voltage, it is in ANALOGUE MODE.
Understanding these two modes is very important because a transistor in digital mode wastes the least energy. However it cannot amplify a signal that has an amplitude less than 0.6v. It can only amplify a signal that is greater than about 0.7v.
That's why some circuits need both types of stages.
A well-designed circuit takes the least current in quiescent mode.
We have also shown how one stage transfers energy to the next stage via a capacitor. But a capacitor creates losses.
Direct-coupling transfers more energy and has no loss.
When designing a circuit it is best to refer to the circuits covered in this eBook, to prevent designing something that may not work correctly.
We have exposed many poorly-designed circuits in our "**Spot The Mistake**" eBook, as explained above.

CLIPPING AND DISTORTION

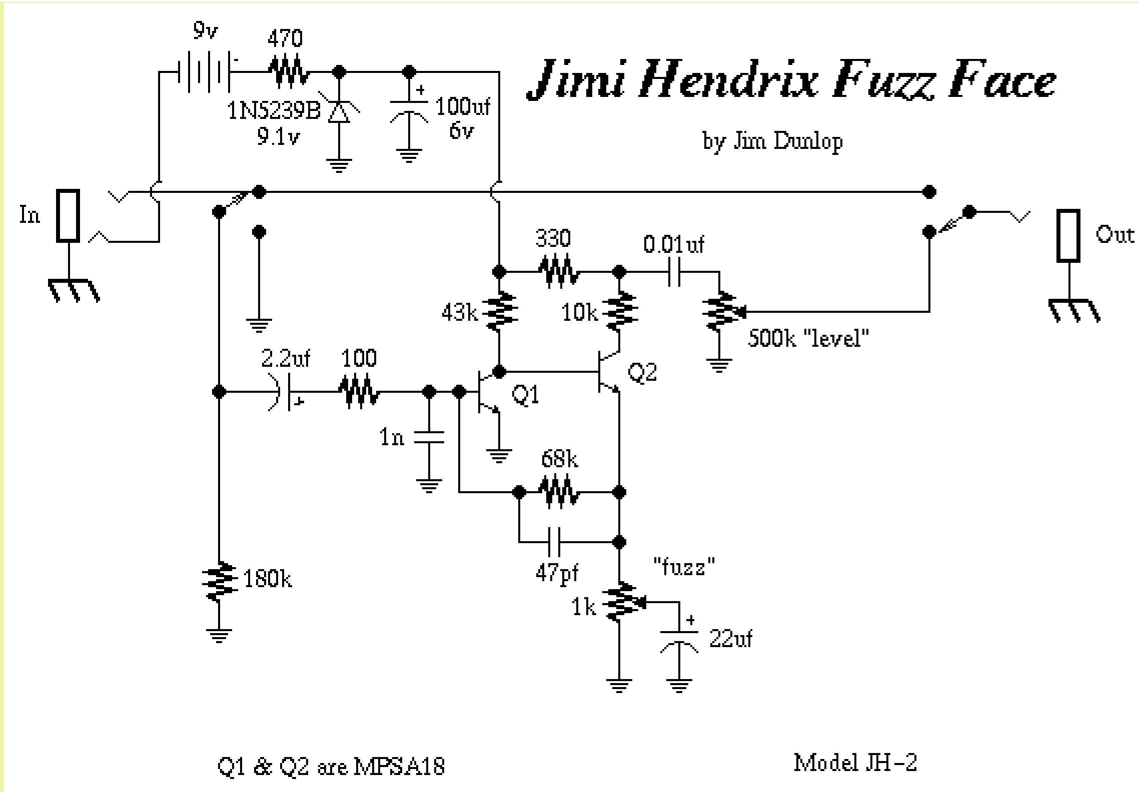
Most Analogue circuits require a stage to reproduce a signal as accurately as possible. After all, we don't want an amplifier to be distorted.
However some analogue circuits are designed to distort a signal. Therese can be classified as "EFFECTS" circuits and the most common is a guitar effect called FUZZ. A Fuzz circuit clips a signal so the full amplitude is not delivered to the output.
There are many ways to distort a signal (or process a signal) so a desired effect can be achieved and there are dozens of names for these circuits.
There is no "electronics rationale" behind the design of these circuits and many of them come from experimenting and placing components in unusual places to create positive or negative feedback or overdrive a stage or even under-drive the active component (usually a transistor or op-amp).
There are hundreds of circuits to create these "EFFECTS" and here are some:

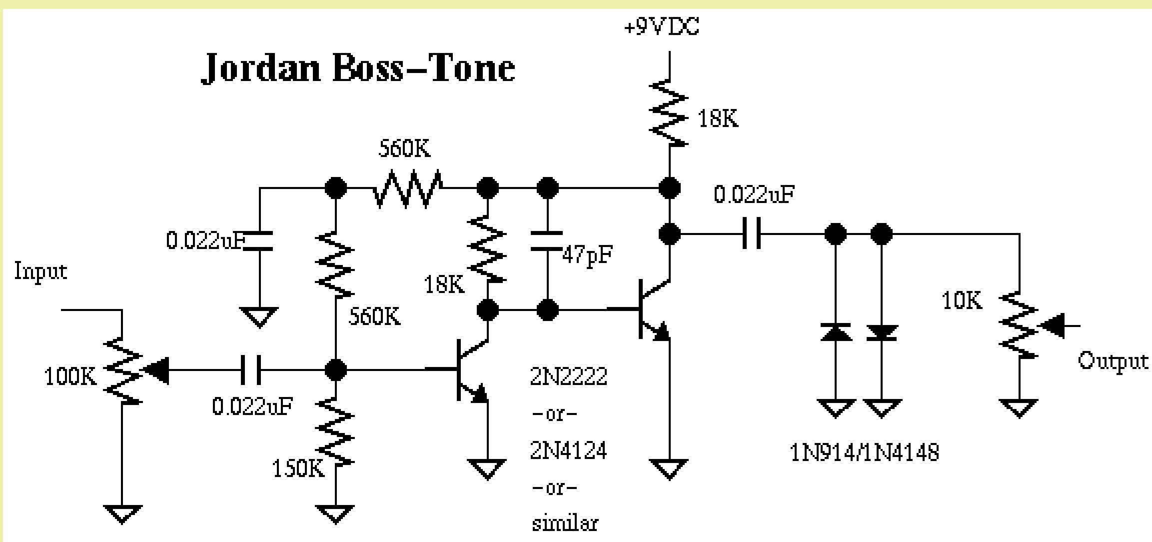


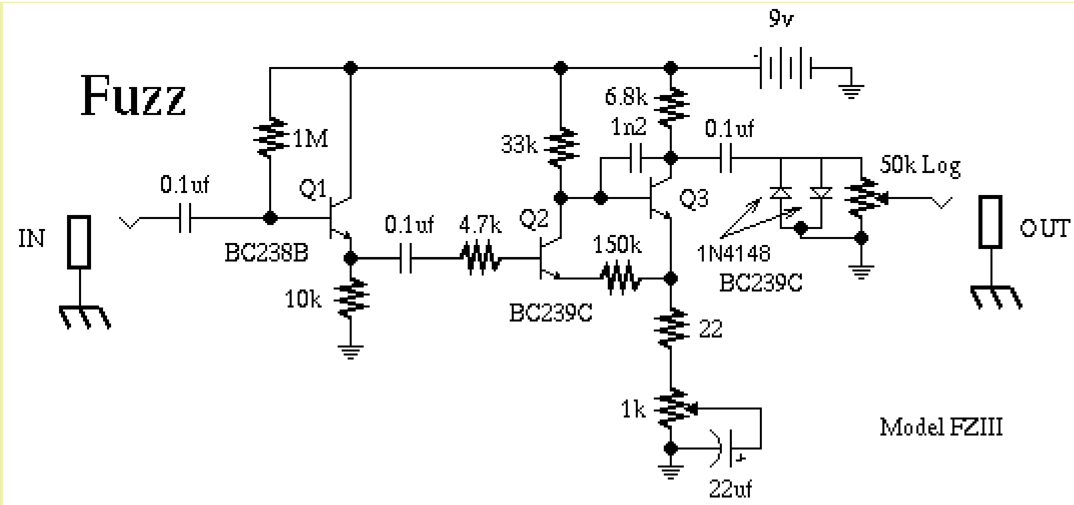
High Frequency Brightener

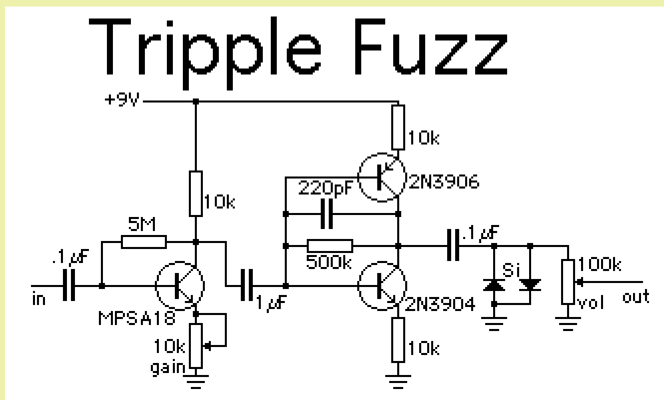


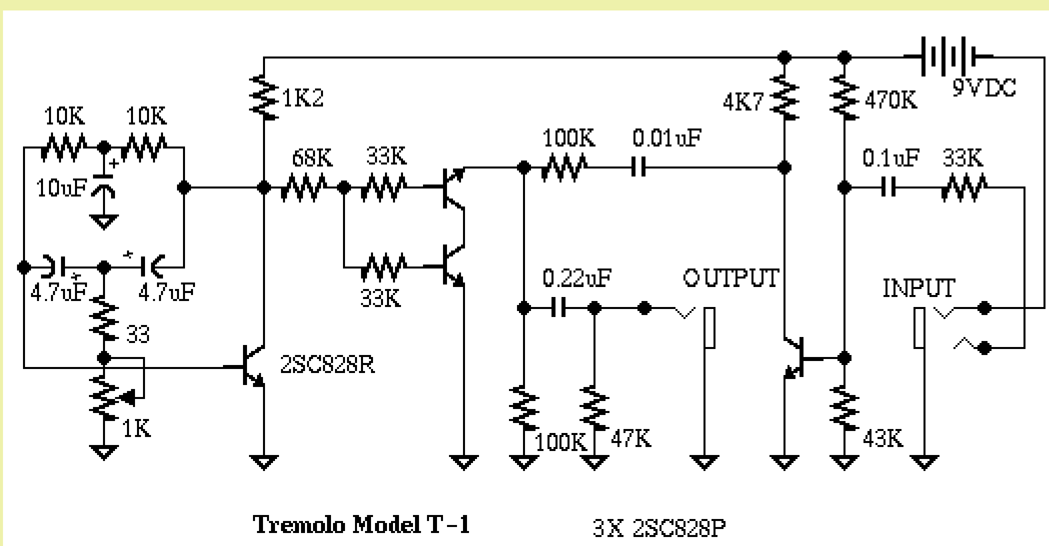
All Signals Brightener


Jimi Hendrix Fuzz Face
by Jim Dunlop
9v
470
1N5239B
9.1v
100uf
6v
In
Out
330
0.01uf
43k
10k
500k "level"
2.2uf
100
Q1
Q2
1n
68k
47pf
"fuzz"
1k
22uf
180k
Q1 & Q2 are MPSA18
Model JH-2


Jordan Boss-Tone
+9VDC
18K
560K
0.022uF
47pF
Input
18K
560K
10K
100K
0.022uF
2N2222
-or-
2N4124
-or-
similar
150K
1N914/1N4148
Output


Fuzz
9v
6.8k
1n2
0.1uf
1M
33k
50k Log
0.1uf
Q1
Q3
IN
0.1uf
4.7k
Q2
OUT
BC238B
150k
1N4148
10k
BC239C
BC239C
22
1k
Model FZIII
22uf

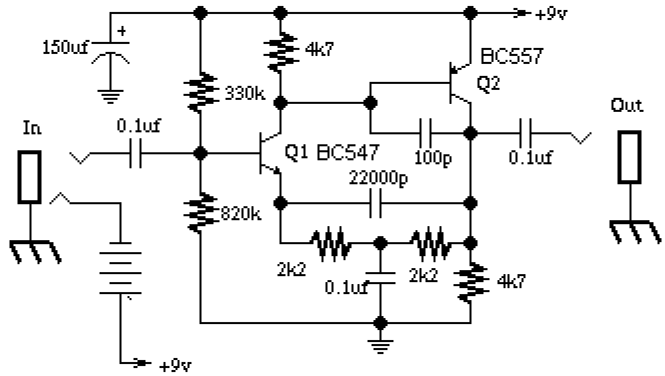

Tripple Fuzz
+9V
10k
2N3906
220pF
10k
5M
.1μF
500k
100k
Si
in
1μF
2N3904
vol
out
MPSA18
10k
gain
10k

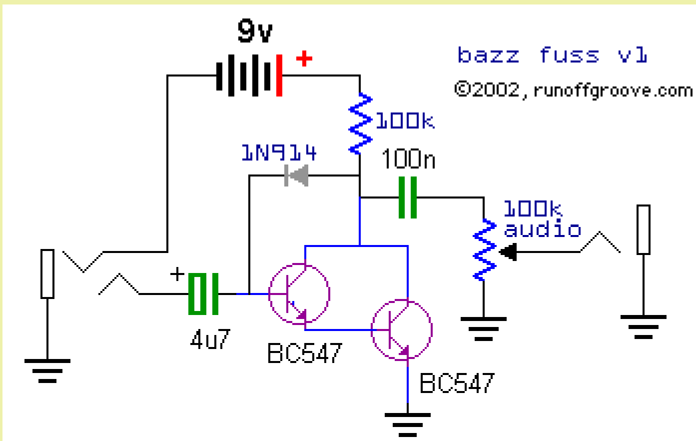

1K2
4K7
470K
9VDC
10K
10K
100K
0.01uF
68K
33K
0.1uF
33K
10uF
33K
4.7uF
4.7uF
0.22uF
OUTPUT
INPUT
33
2SC828R
1K
100K
47K
43K
Tremolo Model T-1
3X 2SC828P

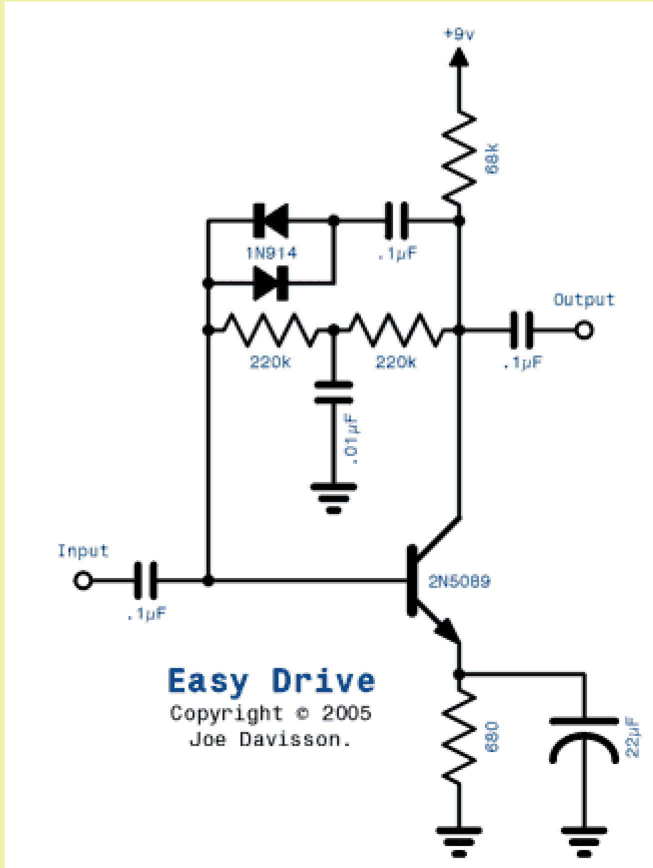
Tone Booster

peaks frequencies at 5000 Hz

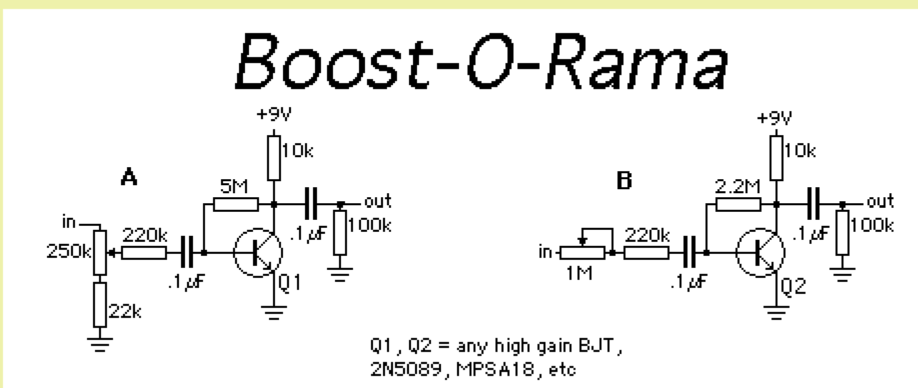
for a "cleaner and more penetrating" sound

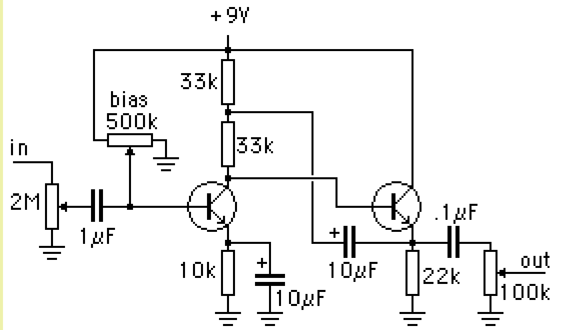






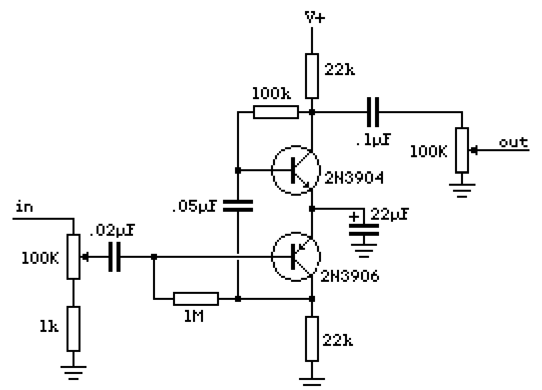
An OVERDRIVE Circuit



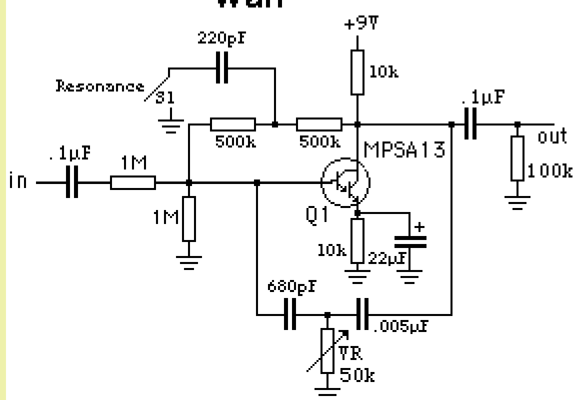


FUZZ and OVERDRIVE

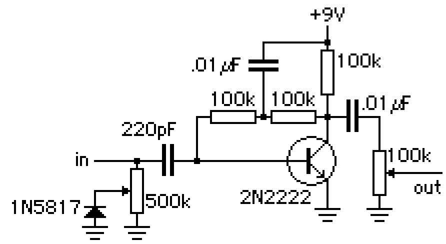
Harmonic Jerkulator



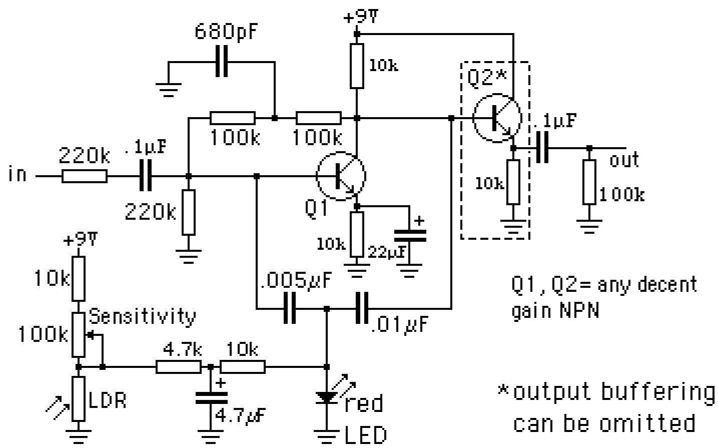
Wah



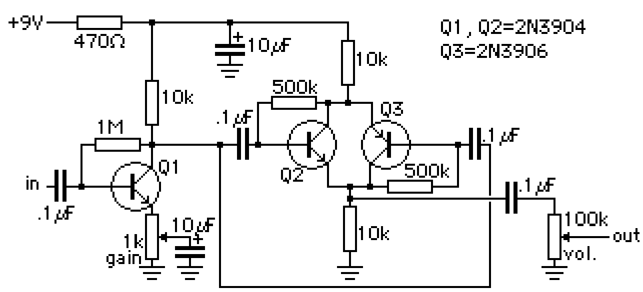
LofoMofo

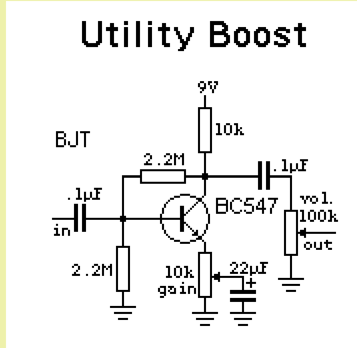


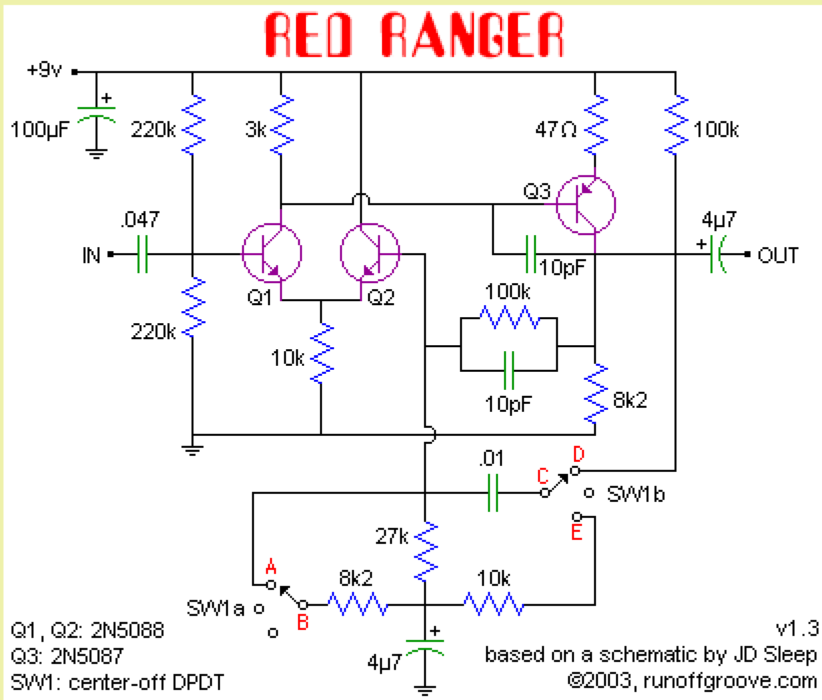
Photon Filter

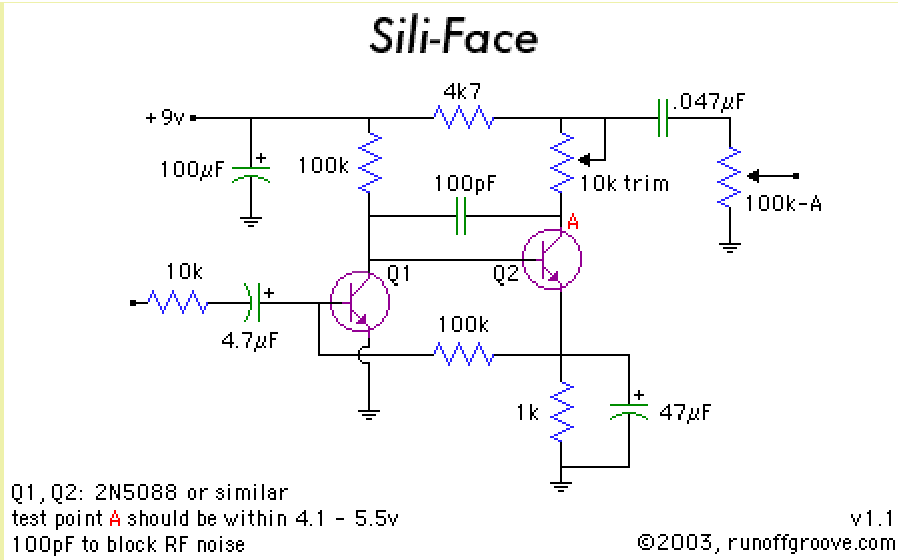


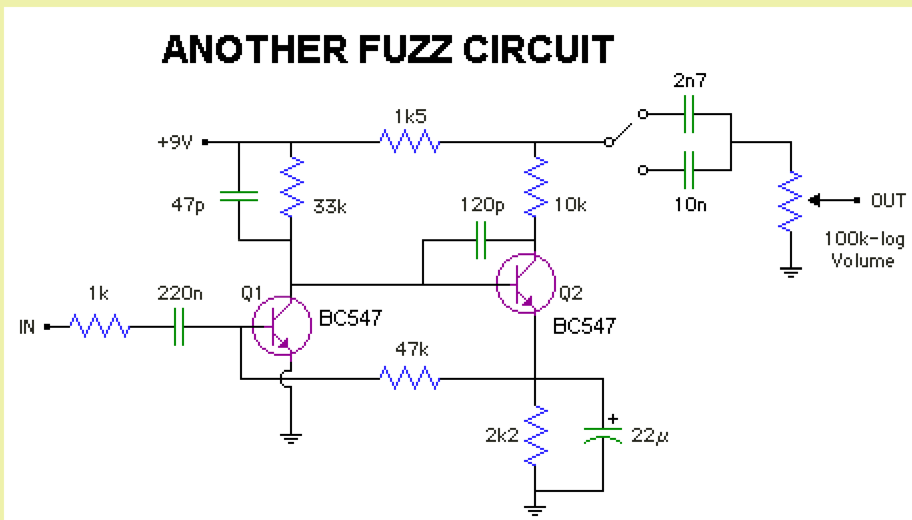
DECENT OCTAVE UP




Utility Boost
9V
10k
BJT
2.2M
.1µF
.1µF
in
BC547
vol.
100k
out
2.2M
10k
gain
22µF


RED RANGER
+9v
100µF
220k
3k
47Ω
100k
Q3
.047
IN
4µ7
OUT
10pF
Q1
Q2
100k
220k
10k
10pF
8k2
.01
D
C
SW1b
E
27k
A
8k2
10k
SW1a
B
Q1, Q2: 2N5088
Q3: 2N5087
SW1: center-off DPDT
4µ7
v1.3
based on a schematic by JD Sleep
©2003, runoffgroove.com

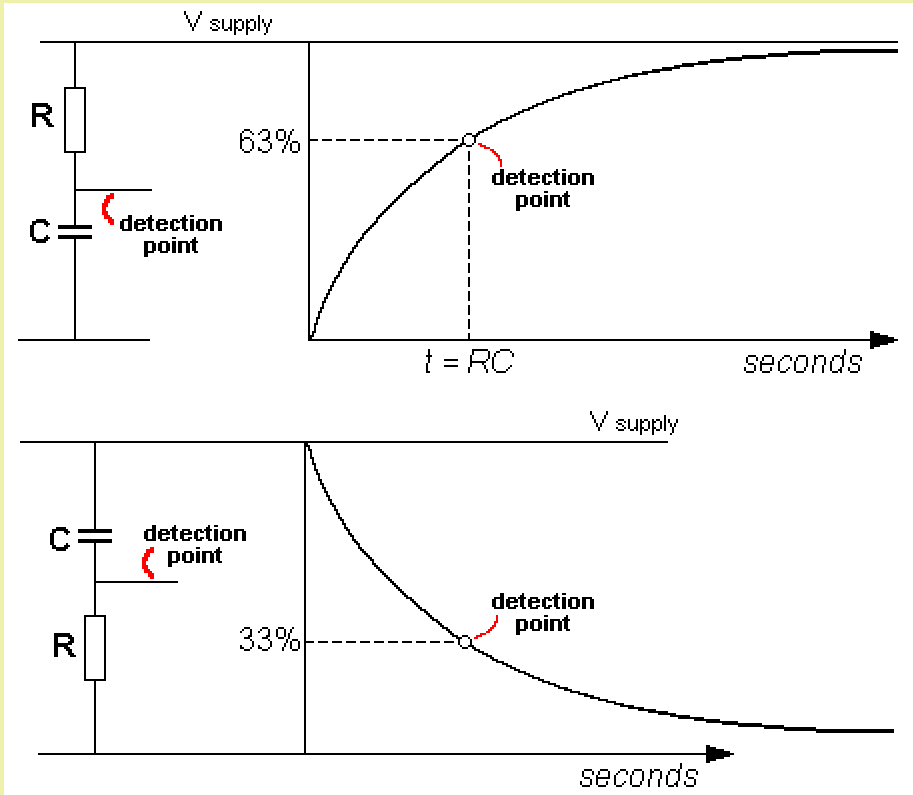




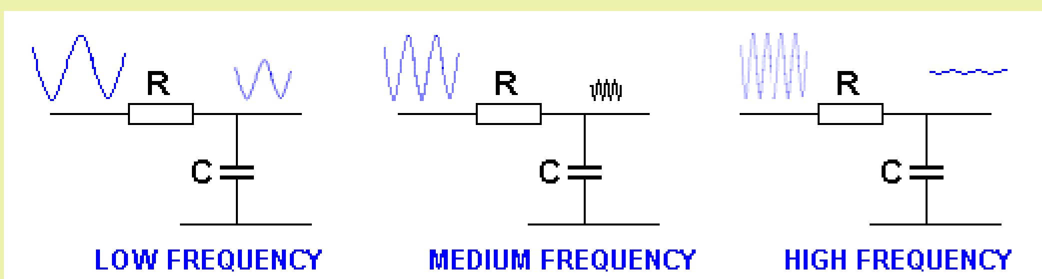
The following website has SOUND CLIPS for lots of different effects:
http://www.home-wrecker.com/salvo.html#bazzfuss

Integration and Differentiation

We are going to show how two components, (a resistor and capacitor - in series) produces different results according to the frequency of a voltage (signal, waveform) delivered to them. We also have different names for the two "series components," depending on the actual circuit using the components. We have already covered the TIME DELAY circuit and shown it consists of a resistor and capacitor in series. The join of the two components is detected by a transistor or Integrated Circuit and when a particular value of voltage is reached, the circuit produces results as shown below. When the circuit is first turned ON, the voltage gradually RISES when the capacitor is below the resistor or gradually FALLS when the capacitor is above the resistor.



But if we connect the same two components to a rising and falling voltage, a completely different result is produced.
If the input is a sine-wave, the following results are produced when a low-frequency, medium-frequency or high-frequency is supplied to the input:

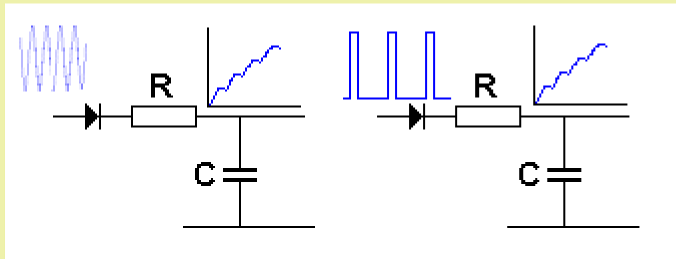


The circuit is a LOW PASS FILTER

You can see the output waveform almost disappears when a high-frequency is delivered to the input. (It disappears in amplitude, but a voltage appears across the capacitor that is approximately the average of the high and low values.)
This means the circuit is capable of removing high-frequency portions of a waveform. If the waveform consists of a mixture of low-frequencies and high-frequencies, only the low-frequencies will appear on the output.
In other words the circuit is a FILTER and it only passes the LOW FREQUENCIES.
In other words it is a **LOW PASS FILTER**.

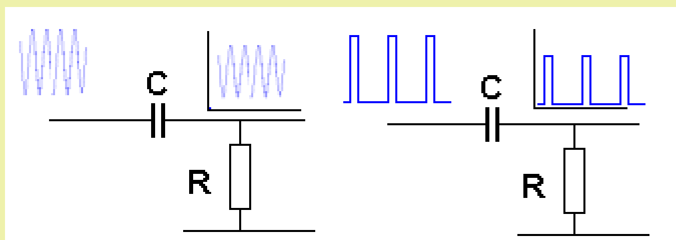
We now look at the circuit above when ANY frequency is delivered to the input. This time we will eliminate

the effect of the waveform when it is falling, by adding a diode to the input.
You will notice a voltage builds-up on the capacitor. This is because the input voltage is charging the capacitor a little-bit more on each cycle. The circuit becomes an INTEGRATOR. It does not matter if the waveform is a sinewave or square-wave - the capacitor gradually becomes charged.



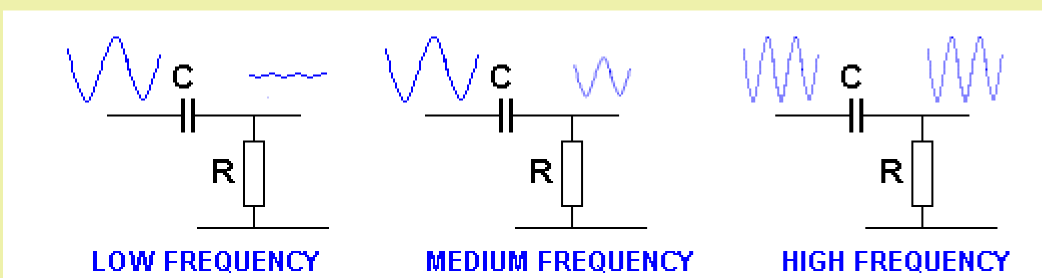
The circuit is an INTEGRATOR
- it gradually charges the capacitor

If we deliver the waveform to the circuit with the capacitor above the resistor, the output is not integrated:



The circuit is NOT an INTEGRATOR

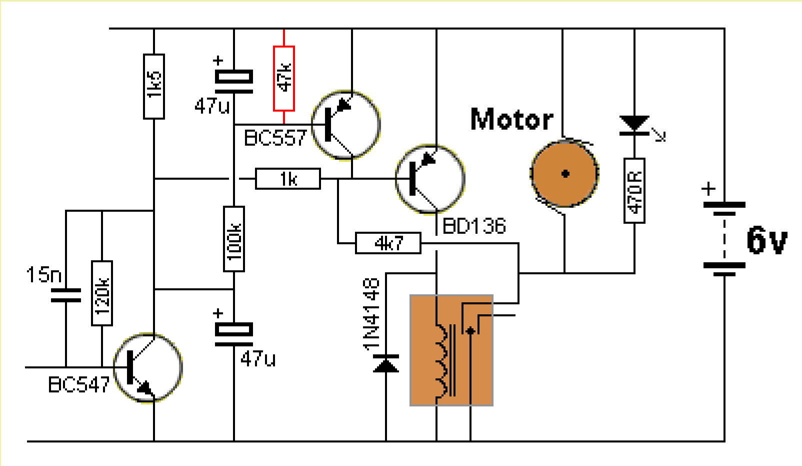
So, what is the purpose of the circuit with the capacitor above the resistor?
The following results are produced when a low-frequency, medium-frequency or high-frequency is supplied to the input:



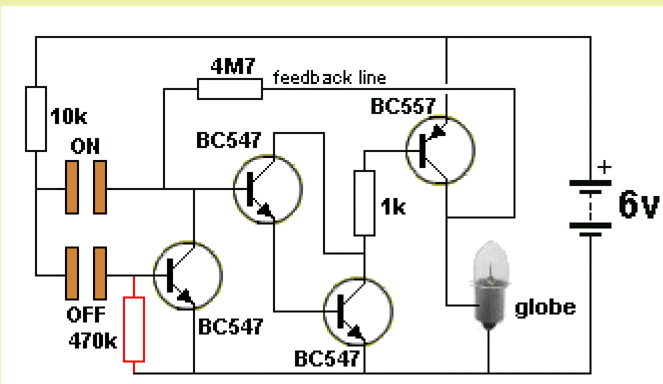
We see the low-frequency waveform is attenuated (reduced) while the high-frequency waveform passes through the circuit.
This produces the name "HIGH PASS FILTER."
It is also given the name "DIFFERENTIATOR."
This means only the high-frequency portions of the input waveform will be delivered to the output.
If we have a waveform consisting of low-frequency and high-frequency components, only the high frequency parts will be delivered to the output.

PULL-UP and PULL-DOWN Resistors

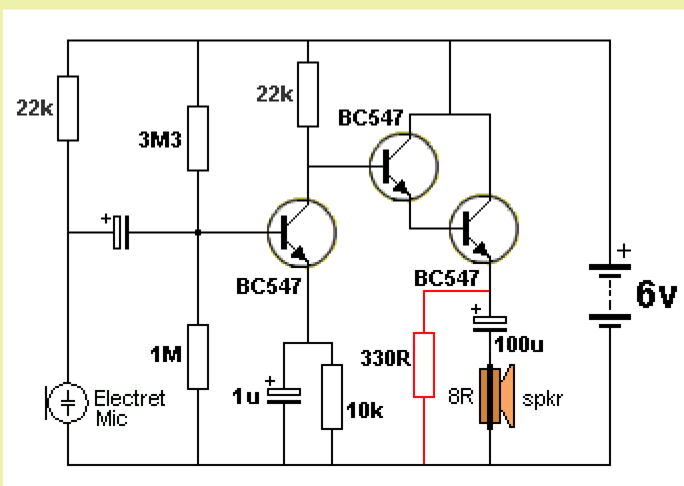
The simplest type of "pull-up" and "pull-down" resistors are shown in the following diagrams:



The 47k is a "Pull-Up" resistor. The designer of the circuit wants the base of the transistor to be at a known voltage when the circuit is sitting around, waiting for a signal. The 47k forms a voltage-divider with the 100k and BC547 and it makes sure the BC557 is turned off when the circuit is waiting for a signal. It is pulling the base "UP" so the BC557 is not turned on.



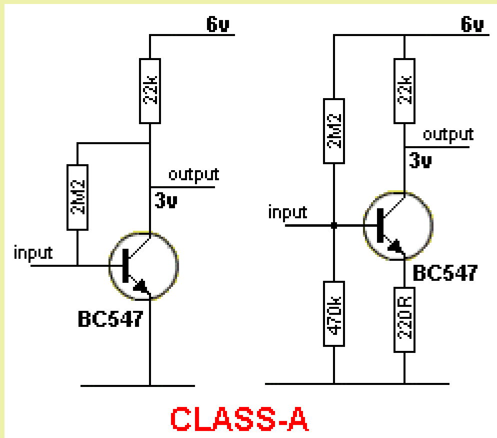
The 470k is a "Pull-Down" resistor. It prevents the BC547 generating a static voltage on the base and turning the circuit OFF.



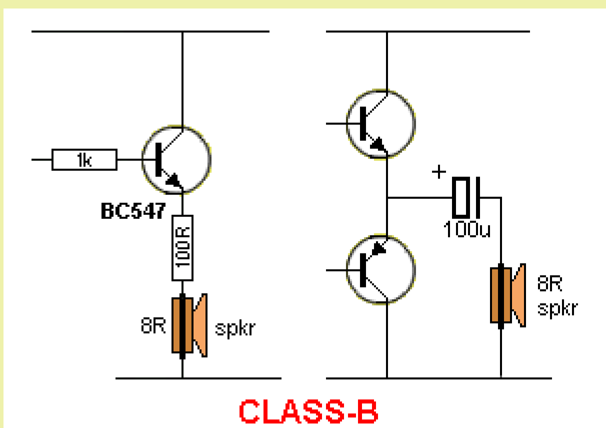
The 330R can be classified as a "pull-down" resistor. It is also part of the load for the output stage.

CLASS-A CLASS-B CLASS-C

Each stage in a circuit can be given a name according to its efficiency. Normally the output stage is the only stage that is classified as "A" "B" or "C" because this is where most of the efficiency or losses occur. However the same criteria applies to the other stages in a circuit and this can give you some indication of the performance of each stage.
The most inefficient stage is classified as **CLASS-A**. It has an efficiency of 25% to 50%.
However it is the best stage for amplifying audio signals as it produces perfect reproduction and amplification. High Fidelity amplifiers are class-A throughout. The stage is biased so the collector is at half-rail voltage. This allows the stage to amplify both the positive and negative portions of the signal.

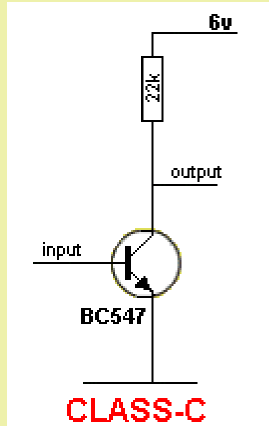


CLASS-B is basically an **EMITTER-FOLLOWER** stage. It is also called **PUSH-PULL** when two emitter-follower transistors are connected together. Push-pull has an efficiency of 78% max. The stage only amplifies the positive portions of the signal. When two transistors are connected, one amplifies the positive portion of the signal and the other amplifies the negative portion of the signal.



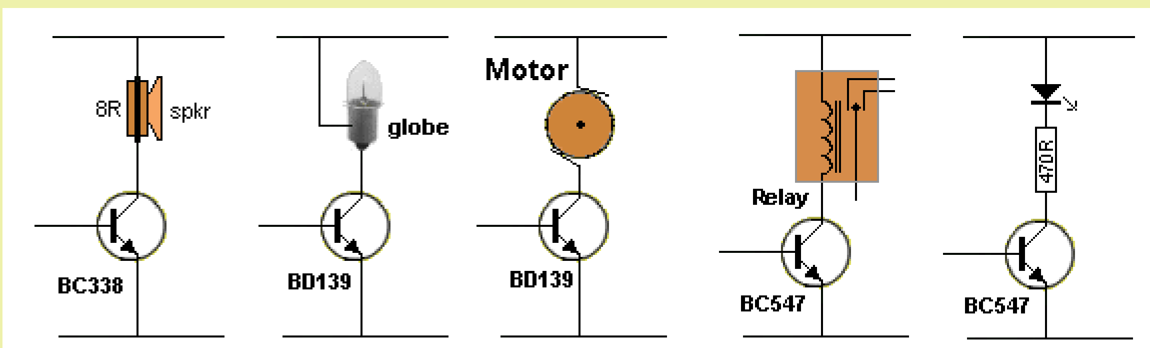
CLASS-C does not have base-bias. It consumes no current when "sitting around" and efficiencies up to 90% are possible.
The energy to turn the transistor ON (and drive the base) must from the input signal. The stage only amplifies the positive portions of the signal and has high distortion, but it can be used in certain

applications with very good results.



THE DRIVER STAGE

Any transistor that drives a **LOAD** is said to be a **DRIVER** in a **DRIVER STAGE or OUTPUT STAGE**. A **LOAD** is generally a relay, motor, globe, LED or other device that requires a **CURRENT**.
The following diagrams show a DRIVER (or OUTPUT) TRANSISTOR driving a LOAD:



The transistor driving a LOAD

In most circuits, achieving a **CURRENT** to drive a load is the most difficult thing to do.
The **voltage** for the LOAD is easy to get. It is the voltage of the supply. The supply (RAIL VOLTAGE) can be set to match the requirement of the LOAD. If you have a 6v motor, use a 6v supply. If you have a 12v relay, use a 12v supply.
Achieving (getting, supplying) the **current** for the LOAD is the requirement of the transistor - the DRIVER transistor or commonly called the OUTPUT transistor.
The first thing you have to know is the amount of current for the LOAD. This is generally expressed in milliamp (mA) or Amp (A). 1,000mA = 1Amp.
In some cases this is easy. It is on the specification-sheet - such as a LED requires 25mA and a relay requires 90mA. But if a relay states "12volt 100R", you will have to work out its current. It's a simple Ohm's Law equation:

$$I_{(amps)} = \frac{V_{(volts)}}{R_{(ohms)}}$$

To save mathematics, we have provided the current requirement for a number of relays:

5v relay 100 ohms   50mA
5v relay 240 ohms 20mA
9v relay 100 ohms   90mA
9v relay 240 ohms   40mA
12v relay 100 ohms   120mA
12v relay 240 ohms   50mA

The current for some loads is unknown. For example, a 6v or 12v motor will take more current when starting or when heavily loaded. The starting current can be 6 times the running current and this is what the driver transistor must be able to provide. In fact the running current is not known until you try the motor. It can be 50mA, 100mA, 250mA or even 1amp. The starting current can be 6 times the running current.
This is what you have to do:
Connect the motor to the supply (without a transistor driver) and add an ammeter in series with one lead. Turn the motor ON and hold the shaft. Quickly read the current. Release the shaft and read the running current.
Suppose a motor requires 600mA to start and 100mA to run. In other words, the motor will take 100mA when lightly loaded and 600mA when heavily loaded.
The driver transistor will be required to supply 600mA to start the motor (and when it is under load) and when it is running under almost no-load, the current will drop to 100mA.

For a transistor to supply 100mA to 600mA to the motor, we must deliver current to the base. The transistor simply amplifies the current we supply to the base. The amplification factor is called the CURRENT AMPLIFICATION or CURRENT GAIN and is normally 100, but this only applies when the transistor is lightly loaded.

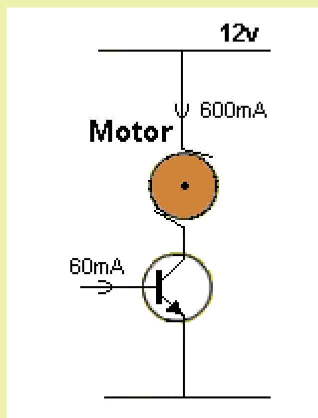
CURRENT GAIN
If a transistor has a CURRENT AMPLIFICATION of 100, 1mA into the base will allow 100mA to flow in the collector-emitter leads (collector-emitter circuit).
But if a transistor is designed to handle 100mA, it will only deliver about 50mA when 1mA enters the base.
It may take 2mA base-current to get to 70mA, 5mA to get to 80mA and 10mA to get to 100mA.
To deliver 100mA, you will need a transistor capable of delivering about 300mA. That's because the larger transistor has a larger junction and is capable of handing the current.
For example, you will need a 300mA transistor to handle 100mA and a 1 or 2 amp transistor to handle 600mA. This is a fact that is rarely explained.
When you choose the right transistor, it will remain fully saturated when 100mA is flowing and the voltage across the collector-emitter will be less than 0.5v. In other words, the transistor will remain FULLY SATURATED or FULLY CONDUCTING.
When the current exceeds the maximum rating, the transistor falls out of conduction. In other words the voltage across the collector-emitter terminals will increase above 0.5v and will gradually rise to 1v, 2v, 3v, or more as the current increases. When this happens, the wattage dissipated by the transistor increases and it gets very hot. The transistor may be able to deliver the higher current but the voltage across the load will be reduced as some of the voltage is lost across the transistor.

Let's take this in more detail:
When a transistor is fully saturated and passing 600mA, the collector-emitter voltage will be as low as 0.2v to 0.5v. The wattage dissipation will be: P=VI = 0.2 x.6 = 0.12watts or P=VI = 0.5 x.6 = 0.3watts
If the transistor comes out of conduction and produces 3v across the collector-emitter terminals, the wattage dissipation increases to: P=VI = 3 x.6 = 1.8watts This is an enormous increase in heat produced by the transistor. That's why you don't want a transistor to come out of conduction.

How do you know if a transistor has a gain of 10 or 100?
You don't. There is no way to know if a transistor has a gain of 10 or 100.

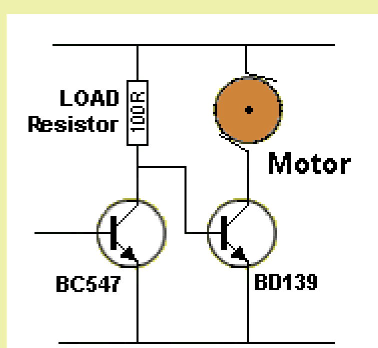
However if you follow our suggestions, you will be able to achieve the maximum gain:
Select a transistor capable of delivering 2, 3 or 5 times more current than is needed for the project you are designing. This will allow it to operate in its HIGH GAIN region because it will not be over-loaded.
Feel the temperature-rise of the transistor and use a heatsink to prevent it over-heating.

A transistor capable of supplying 1amp will be operating near its maximum when supplying 600mA and the base will need 60mA.
In the diagram below, the transistor is not controlling the current. It simply supplies the current demanded by the motor. If the motor requires 100mA, the required current will flow though the collector-emitter leads of the transistor. When the motor "asks for" 600mA, the transistor will deliver the current.
For this current to be available to the motor, the transistor must be turned ON and fully saturated.
The 60mA base current flows ALL THE TIME so that when 600mA is required by the motor, the transistor will deliver the current.
The following diagram shows the current required by the motor. Here's the important point. The circuit must be designed so that it can deliver 600mA **AT ANY TIME**. This means the transistor must receive a base current of 60mA **AT ALL TIMES**.
If you use a high-power transistor, it may have a gain of 50 or more when delivering 600mA and the base current will be lower, but we will take the case of the transistor having a gain of 10 when 600mA flows.



Base Current

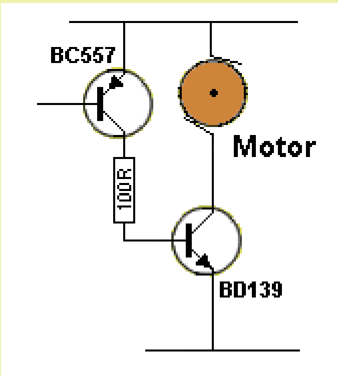
Base-current:
Base current comes from the previous stage in a circuit.
There are two ways to deliver this current:
1. via a load resistor
2. via a transistor.
We have already seen the inefficiency of delivering a current via a load resistor, as shown in the following circuit:



Base current supplied via a LOAD resistor

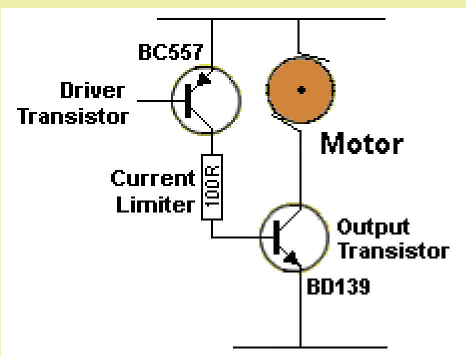
In the circuit above, current is always flowing through the 100R LOAD Resistor. The BC547 is merely diverting the current from the base of the output transistor to the 0v rail. We will not be describing this circuit arrangement.

It is much more efficient to deliver a current via the following type of circuit:

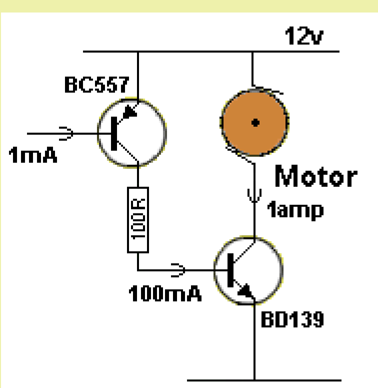


In the circuit above, current is only flowing through the 100R LOAD resistor when the PNP transistor is turned ON. The 100R CURRENT LIMITING resistor determines the base current for the output transistor.

We have now designed the best circuit for driving a LOAD:

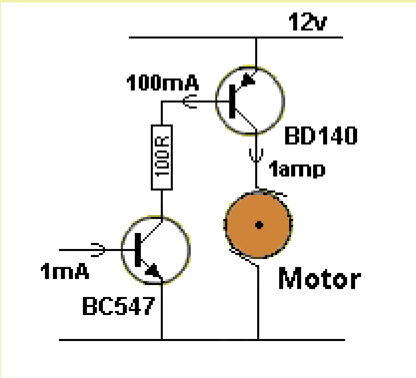


The approximate current in each leg of the circuit for 1Amp LOAD is as follows:



This means 1mA will control (deliver) 1amp (1,000mA) into a LOAD.

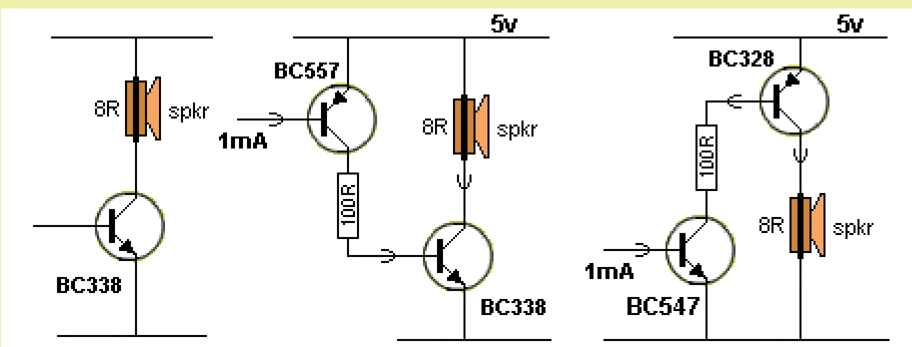
Here is the PNP-output circuit:



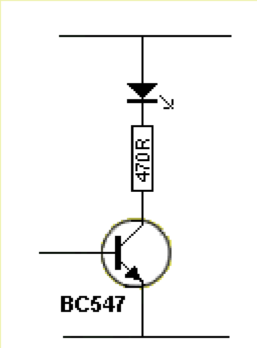
In Summary: When designing a circuit, we allow a current-gain of 100 when a transistor is lightly loaded and a gain of 10 when fully loaded. The driver transistor will have a gain of between 100 and may drop to 10 when full current flows. This means it will need 1mA base current for 100mA it delivers to the load when the gain is 100, but will need 10mA for 100mA, when it has a gain of 10.

This also applies to a globe (lamp) as the load. A globe requires 6 times more current to begin illumination because the filament is cold and its resistance is less than when it is hot.
To make sure the circuit will illuminate the lamp, the driver transistor must be able to deliver up to 6 times the operating current for a very short period of time.

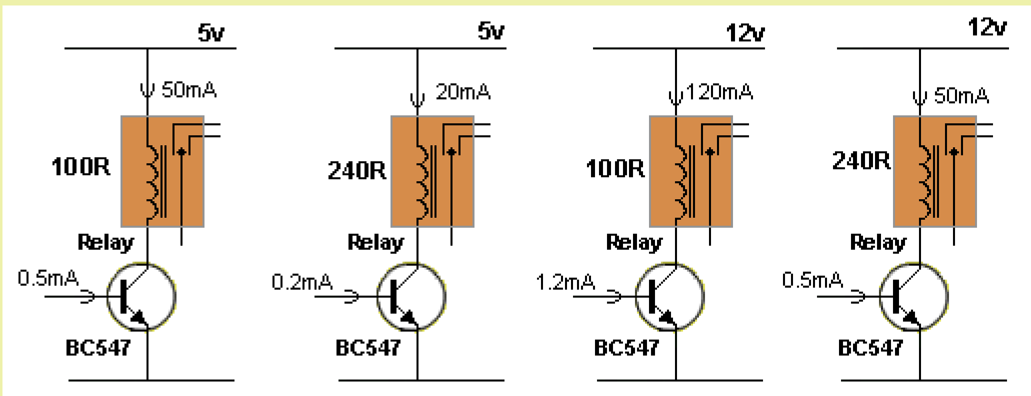
A transistor driving a speaker requires the same driver and output arrangement as driving a motor as it is a very low (impedance) resistance.



The situation is different with a LED. The current required for a LED is small and a small-signal transistor can supply the current and have a gain of 100. The current for a LED will be about 25mA and the base current will be less than 0.25mA



The current for a relay can also be provided by a small-signal transistor and the gain can be 100.



The base current must come from a previous stage

For low-current requirements, use a BC547 for the driver/output transistor. A BC547 will handle up to 100mA.
Similar transistors include: 2N2222A, BC107, BC108, BC109, BC142,BC182L, BC337, and many others.

How to Design a DRIVER STAGE

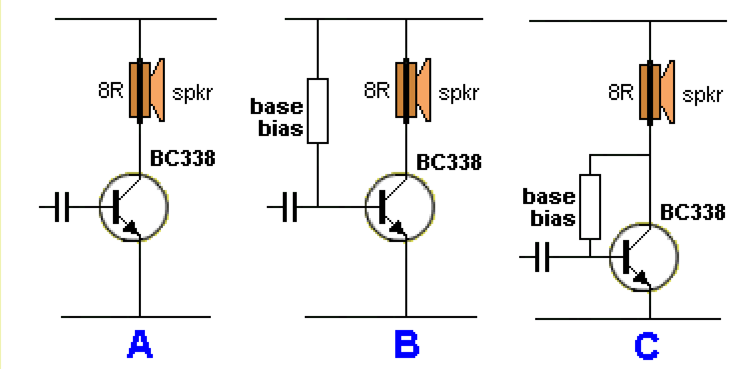
For a HIGH CURRENT requirement, the NPN driver transistor needs to handle 1 amp or more.
For 1 amp use: BC142, BC337, BD131, BD139,
For more than 1 amp use: 2N3054, BD131, TIP31A and many others.

Use a heatsink.
To make sure the transistor stays IN CONDUCTION, measure the collector-emitter voltage when under FULL LOAD. The collector-emitter voltage must not be above 1v.

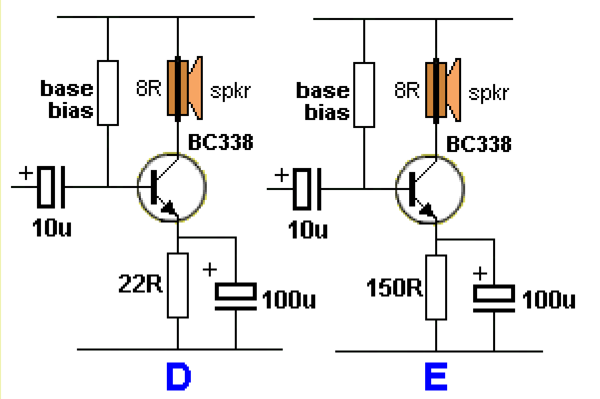
An 8R speaker puts a very heavy demand on any supply rail and this can cause glitches that may affect the operation of other sections of the circuit.

Fig A shows a speaker connected to a driver transistor. The circuit will work but the first 0.5v of the signal will not be reproduced as the transistor does not turn on until the base sees 0.6v. The circuit takes no current in quiescent mode as the transistor is not tuned on. The output will be distorted.
Fig B shows a base bias resistor connected to the positive rail. This resistor will have to be a low value (about 2k2 to 10k) to turn the transistor ON so that the collector will be at about half rail voltage. This will allow both the positive and negative excursions of the signal to be reproduced.
Fig C shows the transistor in self-bias mode. Figs B and C are very similar. The resistance of the base bias resistor will be slightly lower in fig C and selecting the right value will provide about half rail voltage

on the collector.

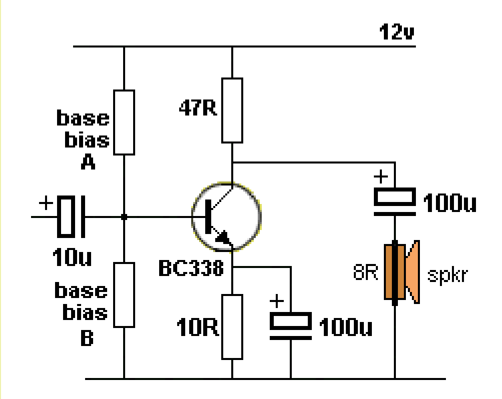


But the problem with all these circuits above is the high current taken by the stage.
As you can see, the load is only 8R and if the transistor is partly turned ON, the idle current will be very high.
This can can be reduced by using the following circuits. The output volume will be reduced, but the current will be reduced considerably.
In the circuits above, the output impedance is 8R. In the circuits below, the output impedance has been increased to 30R and 158R.



The secret to the good performance of stages D and E is due to the 100u on the emitter. This electrolytic turn the stage into a common-emitter amplifier, just like circuits A, B and C, as far as the audio signal is concerned, but turns the LOAD into 30R or 158R as far as the DC current is concerned.
We get the best of both conditions at the same time.

DESIGNING AN OUTPUT STAGE



The circuit at the left shows an output stage as described in the video above, by the "Professor."
He tried to explain the base-biasing but failed.
In fact he did not know what he was talking about.
That's because the operation of the circuit is much more complex than you think.
The circuit has two features. The H-bridge design allows a known operating-point to be produced, even though the gain of the transistor may change from one device to another.
Suppose the transistor is replaced with another having a higher gain.
The collector current will increase and more current will flow though the emitter resistor. This will produce a higher voltage across the emitter resistor and the difference

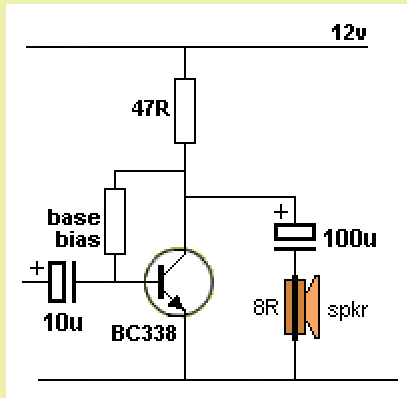
between the base voltage and the emitter will be reduced.

This will turn the transistor OFF slightly and maintain the original conditions.
The second feature of the circuit is the electrolytic in series with the speaker. This allows **only** the AC portion of the waveform to enter the speaker and the cone is not "pulled" due to DC flowing though the voice coil.
However, the operation of the circuit is very complex, so we will explain it this way:
The design of the circuit starts by selecting the value of base bias resistors A and B. The resistors are chosen so that a voltage of about 0.7v is produced on the emitter. This allows the stage to be turned ON with about the lowest quiescent current. (This will produce a voltage of about 0.7 x 47 = 3.3v across the load resistor.)
To get 0.7v on the emitter, we need 1.4v on the base. This gives us the ratio of base bias resistor A and base bias resistor B.
The next thing we consider is the maximum current we want to flow through the load resistor. When the transistor is fully turned ON, this current can be as high as 230mA.
Let us allow the base current from the divider to be 100mA. The additional current will be created when the signal arrives and turns the transistor ON more.
Suppose the transistor has a gain of 100. This means the base current must be 1mA.
This will cause 100mA to flow through the 10R emitter resistor and produce a voltage of 1v.
The base voltage will be 1.7v.
The voltage across base bias resistor A will be 10.3v
The next design-feature to remember is this:
The current flowing through the base voltage-divider (resistors A and B) should be 10 times the base current to provide stable operation.
This means the current through base bias resistor A is 10mA.
The value of base bias A is: 10.3/0.01 = 10.3k
The value of base bias B is: 1.7/0.009 = 1.8k
Forget about the actual amplitude of the incoming signal.
What happens with the incoming signal is this:
The signal-peak gets converted by the 10u electrolytic to produce either a 2mA flow into the base or it cancels the 1mA flow to produce 0mA into the base.
The 100u electrolytic on the emitter prevents the emitter rising or falling and the stage operates just like the emitter is connected directly to the 0v rail.
When the incoming signal cancels the 1mA into the base, the transistor is turned off and the 47R charges the 100u connected to the speaker. This current flows through the speaker to shift the cone. A voltage develops across the electrolytic and energy is stored in it.
When the signal rises, up to 2mA flows into the base and the transistor is fully turned ON.
The energy in the electrolytic flows through the speaker and moves the cone in the opposite direction.

CONCLUSION:

The stage takes considerable current when "sitting around" and this is one of the disadvantages of a "Class-A" stage. If you want low quiescent current - use a class-B output stage.
The stage has a low input impedance (about 1k8) however it is driving an 8R load (the speaker) and this is a ratio of more than 100:1 and the stage is achieving a considerable "conversion."
You can call this circuit an INTERFACE, BUFFER, AMPLIFIER, DRIVER, POWER-AMPLIFIER, or MATCHER. It does all of these things.
The circuit must consume about "half-current" when "sitting around" so the incoming signal can increase the current to full-current or reduce it to almost zero, so the output signal is not distorted.
The "design-feature" involving the two resistors on the base can be changed to only allowing 2 or 3mA as "bleed current" so the input impedance is higher.
This will make the 1k8 resistor as high as 1.8 x 3 = 5.4k and the incoming signal will not be attenuated as much. The attenuation applies to both the rise and fall of the signal as this 1k8 (5k4) is directly across the signal.
It's all a matter of building the circuit and see how it performs as the transistor is at its limit of heat dissipation in this amplifier.

A simpler circuit is shown here. The base-bias resistor is chosen so that half-voltage appears on the collector and the transistor is self-biased so transistors with a slightly different gain will operate correctly. This operation is commonly called "Mid-point operation" or "Q-point" operation. For maximum output the load resistor will need to be 8R, but this will create a current-flow that is more than the transistor will handle. That's why we use "class-B" (Push-Pull) output stages.



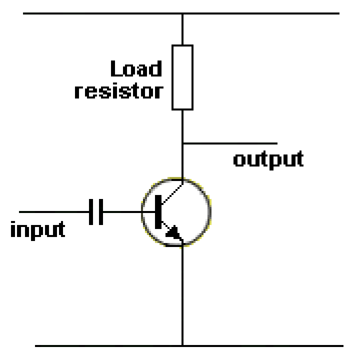
If you want to see the complex mathematics behind the circuit above, click **HERE** for a .pdf from a subscriber and teacher, Tom Wheeler thomas.wheeler@mcckc.edu. He has provided a mathematical assessment to show the power delivered to the speaker can be as low as 8% and in most cases it is not much higher than this value.
This is one more proof that "class-A" configurations are very inefficient.

Mr Wheeler is a lecturer at a tertiary college in Kansas City Missouri USA.
If you are interested in taking a course in electronics, you should investigate the courses available in a college near to you.
It is not easy to get through the jumble of course-names and terminology provided by colleges, technical colleges, institutes, Universities etc, but start by looking on the web and refer the to course-structure to see what topics are covered.
Mr Wheeler's college is **Metropolitan Community College in Kansas City, MO** www.mcckc.edu

Here is a brief listing from the colleges introduction:
The Metropolitan Community College Business & Technology Campus (BTC) is one of five MCC campuses that serve the greater Kansas City area. BTC offers both degree and certificate programs in Computer Aided Design and Drafting (CADD), Cisco Networking (CCNA/CCNP), Engineering Technologies (Mechanical/Electronic/Architectural/Civil), Environmental Health & Safety (EHSS), Electric Utility Lineman, Heating Ventilation and Air Conditioning (HVAC), Industrial Technologies (Instrumentation & Controls/Industrial Maintenance/Energy Efficiency), Solar/Photovoltaic Energy, Precision Machining, Welding, as well as degree completion programs designed for US military veterans and skilled trade apprenticeship completers. We are located at 1775 Universal, Kansas City MO, 64120; please visit our web site at www.mcckc.edu/btc, or call 816-604-5200 to arrange a campus tour.

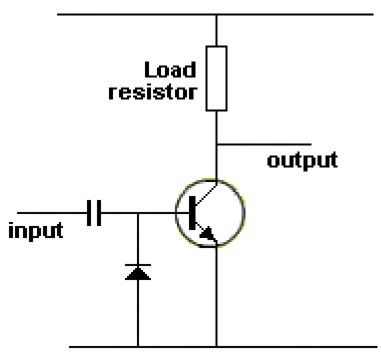
BIASING A TRANSISTOR

We have seen many different ways to bias a transistor and now we look at 3 and compare them.



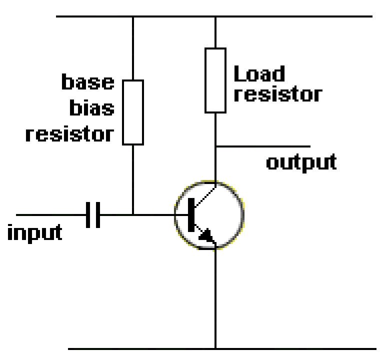
Transistor NOT biased

This transistor is not biased AT ALL. However it will work if the incoming signal is large.
The signal needs to provide all the energy to turn on the transistor and it only amplifies the positive portions of the waveform.
The amplifier is classified as "Class-C."

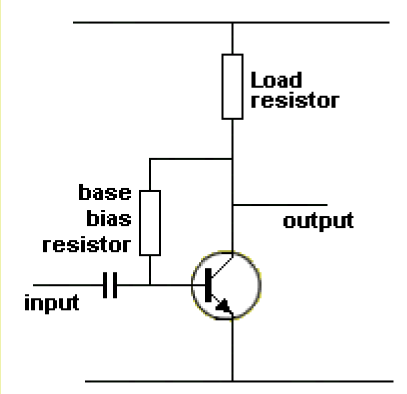


Diode discharges capacitor

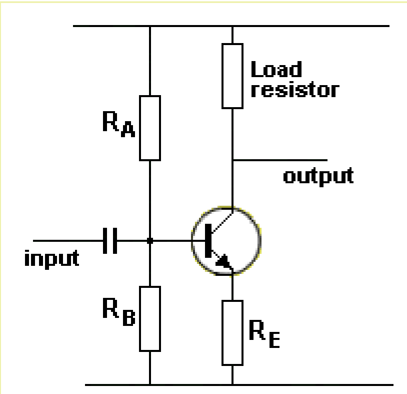
To help discharge the coupling capacitor during the negative portions of the waveform, a diode can be included as shown. It comes into operation during the negative part of the cycle by "flipping over" and conducting when the negative part of the signal is less than -0.6v. All the waveform lower than -0.6v is passed through the diode and the capacitor is discharged during this portion of the signal.
A "Class-C" amplifier takes zero current when "sitting around" (quiescent current), and can be classified a very efficient, however in most cases it will produce distortion.



This circuit uses a base bias resistor between base and supply.
It is a "Class-A" amplifier.
This circuit will work successfully if the base bias resistor is chosen so the collector voltage is mid-rail.
However if you use another transistor with a lower or higher gain, the collector voltage will be higher or lower than for the previous transistor. In addition, the gain of the transistor will change slightly due to temperature and the collector voltage will alter.
This is not a good design as the collector voltage is not stable.

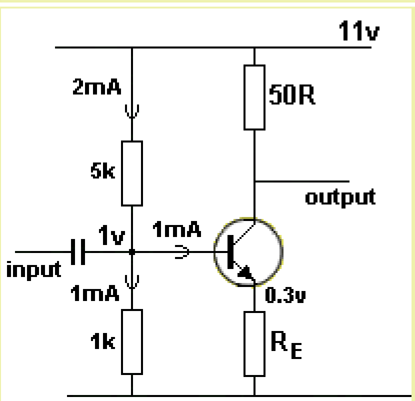


To make the operating-point of "Class-A" amplifier stable, the base-bias resistor is connected as shown.
If the gain of the transistor reduces due to temperature rise, the collector voltage will increase. This will increase the current through the base bias resistor and turn the transistor ON more and lower the collector voltage. It will not reduce to exactly the same voltage as before but the circuit will adjust to a fair extent.
If the transistor is replaced by one with a higher gain, the collector voltage will reduce. This is allow less current to flow into the base and turn the transistor off slightly and the collector voltage will rise. It will not rise to exactly the same voltage as before but the circuit will adjust to a fairly good extent.
This is called a "self-biasing class-A amplifier."



To get a better automatic biasing features as the circuit above, two additional resistors are needed and the circuit forms a bridge. (The word "bridge" comes from "Wheatstone Bridge" where 4 resistors are placed in a square to form a balancing network).
Ra and Rb form a voltage-divider to produce a fixed voltage on the base.
Re is a feedback resistor to create the stabilizing feature.
See: **Emitter Feedback**
Suppose the transistor gets warm on a hot day and looses gain.
The collector voltage will rise and the current through the load resistor will decrease. The current through Re will also decrease and the voltage across it will decrease. This means the voltage between the base and emitter will increase and the transistor will turn ON more to counteract the voltage-rise on the collector.

The value of Ra and Rb are calculated so that 10 times the base current "bleeds" through them. In other words, 10mA bleeds through Ra and 9mA through Rb so that 1mA goes to the base.
This is very wasteful, but let's look at why the bleed current needs to be 10x the base current.
There are two "design factors" in this type of circuit.
1. The bleed current through the voltage divider Ra/Rb is 10 times the current required by the base.
2. The values are chosen so that about 1v appears on the base. This allows the transistor to be turned ON and gives about 0.3v across the emitter resistor. This allows the emitter resistor to stabilize the stage and allows the transistor to turn ON and pull the output as low as possible when a large amplitude signal is delivered.

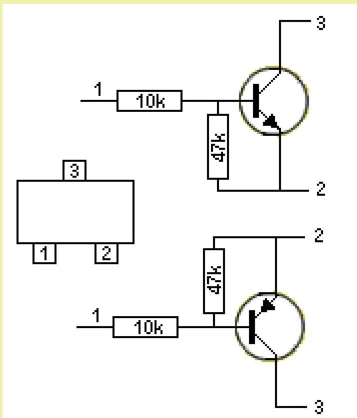


Let's see why the bleed current is 10 times that required by the base.
We will start with a bleed current of 2mA through Ra and 1mA through Rb with 1mA going to the base.
Suppose the transistor has a gain of 100. The current through the collector-emitter circuit will be 100mA and the value of Re will be 3R.
The voltage across the load resistor will be 5v and the voltage on the collector will be 6v.
Suppose the transistor is replaced with one having a gain of 200. We already now the value of the load resistor (50R) and emitter resistor (3R) and the base bias resistors have the capability of delivering 1mA.
What will happen is this: The transistor will turn ON and because 1mA base current is available, it will allow 200mA to flow through the collector-emitter circuit.

The voltage across the emitter resistor will be 0.2 x 3R = 0.6v and the voltage-drop across the 50R will be 0.2 x 50 = 25v. We do not have 25v available (only 11v) and the transistor will turn ON to a point where it is fully saturated. This situation has occurred because the base voltage was able to rise so the base-emitter voltage is 0.7v. Since the transistor is taking only 0.5mA, the voltage across the 1k will theoretically be able to rise to 0.0015 x 1,000 = 1.5v
Now you can see why we want the base voltage to remain stable, so a transistor with a gain of 200 is not

fully turned ON and the same collector voltage is produced for a wide range of gains.

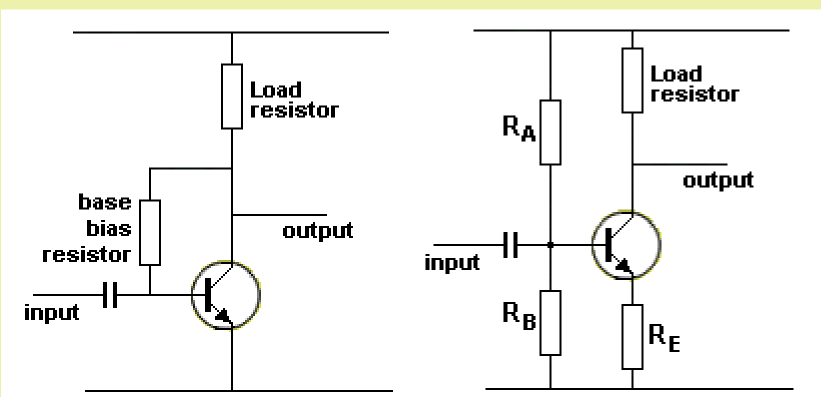
Transistors with internal Resistors



Transistor with Resistors

Some transistors have internal resistors. This includes small-signal transistors, power transistors, Darlington and surface mount devices. You must know if the transistor you are testing has internal resistors because the circuit will be lacking one or two resistors and you will wonder how it has been designed.
In most cases the values of the resistors will be the same as what you would use with a transistor not having internal resistors however if you are designing a new circuit, it is best not to include transistors with internal resistors - you may want to change the value and this is not possible with fixed values.
Some surface mount transistors and Darlington transistors have different values to those shown in the diagram on the left and you need to use a datasheet to determine the exact values. When testing these transistors they will appear to be faulty due to the internal resistors.
The resistor-values are chosen for circuits using the transistors with a medium to high collector current. They are not suited for stages where a very low collector current is required as the base resistor would be 47k to 100k.

Using a Transistor with a Higher Gain

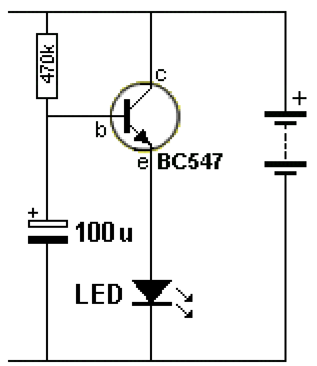


Self Biasing   Bridge Biasing

There are 4 main features of a transistor.
1. Its power-handling capability,
2. Its voltage-rating,
3. Its maximum frequency,
4. Its gain.
What happens if you replace a transistor with one having a higher gain?
The operating point (the "Q-point") will adjust in the Self-Biasing circuit but if the new transistor has a much-higher gain, the collector voltage will be lower.
The Bridge-Biasing arrangement will maintain a more-constant collector voltage when the transistor is replaced with one having a higher gain.

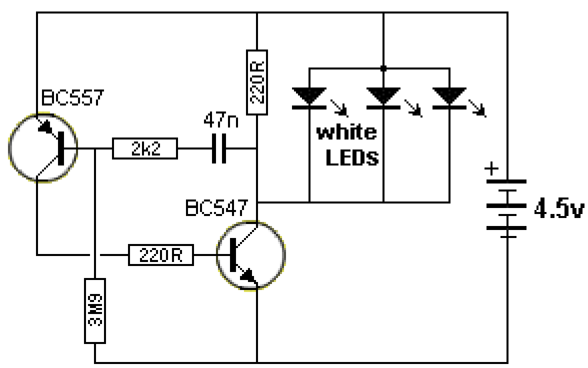
In other words, the **quiescent-point** or **operating-point** (or mid-point for the collector-voltage) of a Self-Biasing or Bridge-Biasing circuit will self-adjust when the gain of the transistor alters. But a higher gain transistor will allow the collector voltage to drop closer to 0v when the incoming signal delivers the high portion of the waveform. The result will be a slightly higher output because the output will go to a lower value than before.
The opposite will occur with a transistor having a lower gain.
See self-biased transistor and biasing for details on how to design the two stages.

Using a Transistor as a CURRENT LIMITER



10 Second Delay

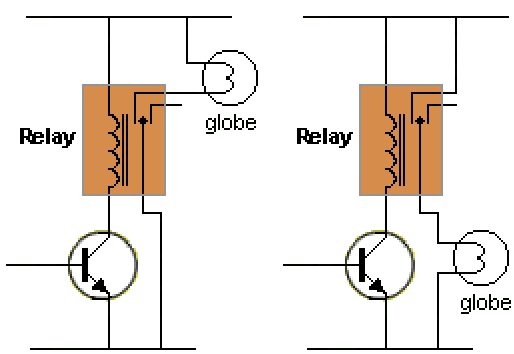
The circuit produces a delay of a few seconds due to the **TIME DELAY** circuit (made up of the 470k and 100u) taking time to charge the 100u. The transistor is an **EMITTER FOLLOWER** and the emitter rises at the same rate as the base but is about 0.7v less than the base.
The circuit does not have a CURRENT LIMITING resistor in series with the LED or in the collector circuit because the transistor can only allow a current between the collector and emitter terminals that is 100 to 200 times more than the current entering the base and it effectively becomes a resistor. If the transistor has a gain of 200, it will be 470,000/200 = 2350 ohms. This will deliver 10/2350 = 4mA.
Another way to explain the circuit is to work out the current entering the base. The voltage across the 470k resistor will be about 10v max for 12v supply and the current will be 0.02mA.
The emitter current will be 0.02 x 200 = 4mA max.
The transistor is acting as a **CURRENT LIMITER**.



BIKE FLASHER

You will notice the absence of a current-limiting resistor on the white LEDs.
There are two reasons why this resistor can be eliminated.
The BC547 transistor can only pass about 100mA and three white LED can easily accept 30mA each.
The LEDs need to be tested to make sure they all have the same "Characteristic Voltage" of 3.3v or 3.5v so they illuminate equally.
Secondly, they are only illuminated for a very short period of time and your eye extends the effect by a feature called PERSISTENCE OF VISION. This means they will never get overheated.
Even though the transistor is seeing about 15mA into the base, it will still only allow 100mA collector current to flow and it is acting as a **CURRENT LIMITER** for the LEDs.

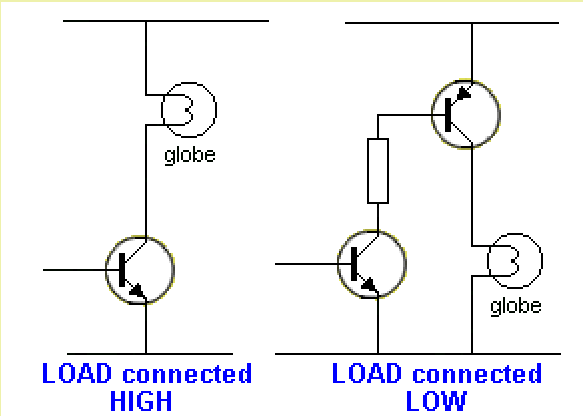
TRANSISTOR REPLACES A RELAY



Globe connected HIGH

Globe connected LOW

You need all the previous discussions to understand how a transistor can be used to replace a relay.
A replacement can only be used in some cases.
The main advantage of a relay is its ability to completely isolate the driving circuit from the load.
That's the main reason why it is used. A transistor does not provide this isolation.
However a relay has a limited life and if the circuit is constantly switching on and off, the relay will soon fail.
There are a number of factors that need to be considered before a replacement can be made.
The first is the way the load is connected. It can be connected "HIGH-SIDE" or "LOW-SIDE."

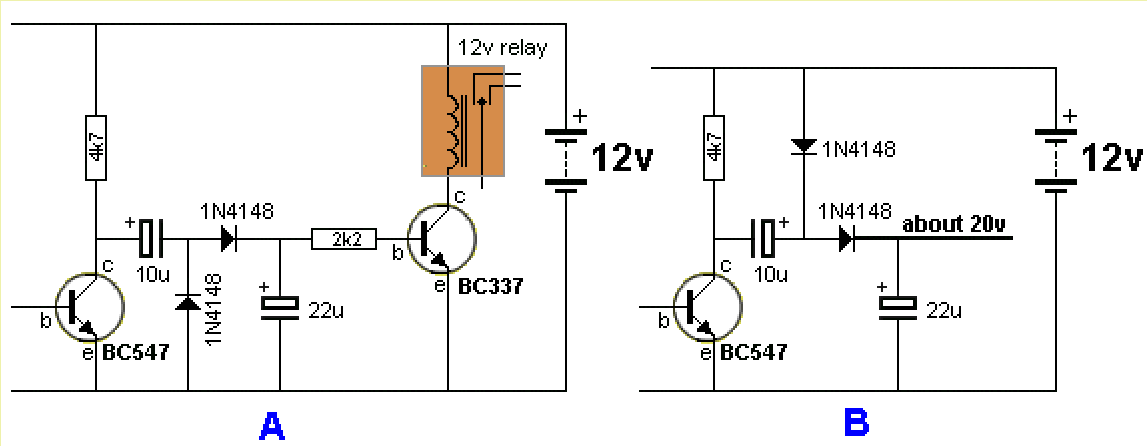


In other words, the load can be connected between the positive and relay to create HIGH-SIDE. (the other terminal of the relay is connected to 0v.)
Or it can be connected between the relay and 0v to create LOW-SIDE. (the other terminal of the relay is connected to positive rail.)
This will determine how the transistor circuit is designed. The other important factor is the current-capability of the transistor. It must be able to handle the current and it must be driven into saturation so that the least voltage is lost across the collector-emitter circuit.
Turning the transistor ON and OFF quickly will also reduce the temperature of the driver transistor.

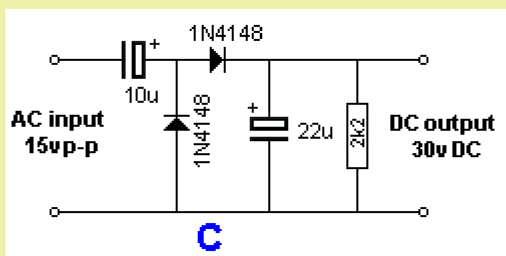
THE DIODE PUMP (CAPACITOR INPUT PUMP)
Also called a CHARGE PUMP.
And the VOLTAGE DOUBLER

There are two circuits in this discussion that look very similar but produce different results.
Circuit A is called a DIODE PUMP or CAPACITOR-INPUT PUMP or CHARGE PUMP and it produces an output voltage that is never higher than rail voltage.
Circuit B is called a VOLTAGE DOUBLER. However it can be called a CAPACITOR-DIODE CHARGE-PUMP or CHARGE PUMP. It produces a voltage higher than rail voltage.

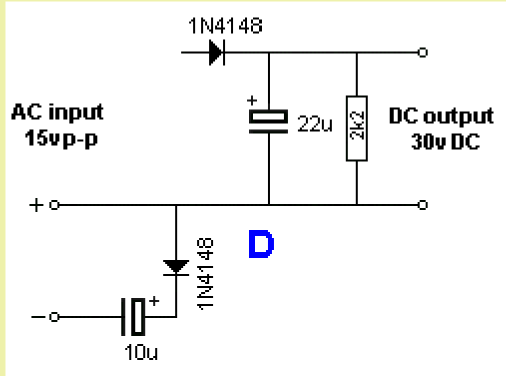
Circuit A is basically designed to activate a relay when the voltage across the 22u rises above 0.7v. Only an AC signal will pass through the 10u and when the BC547 turns off, the 4k7 pulls the positive lead of the 10u towards the positive rail. This causes the negative lead to rise too and a voltage appears at the join of the two diodes. The lower diode has no effect at the moment but the upper diode passes this voltage to the 22u and the electrolytic begins to charge. The 10u also charges. The BC547 is designed to turn on after a short period of time and it pulls the positive lead of the 10u towards the 0v rail. The 10u has a small voltage across it at the moment and the negative lead goes below the 0v rail. As soon as the lead goes -0.7v, the lower diode starts to conduct and it discharges the 10u. Only a small voltage of about 0.9v will be left in the 10u and the BC547 is now designed to turn off. The 4k7 pulls the 10u towards the positive rail and the 22u gets a further small amount of charge. As soon as it reaches 0.7v, the BC337 turns on and energises the relay. The 2k2 allows the 22u to charge to a slightly higher voltage than 0.7v so that the relay remains activated a short period of time after the signal from the BC547 has ceased. This circuit coverts an AC signal into a DC voltage.



Circuit B is a VOLTAGE DOUBLER. The two circuits appear to be very similar. The component values are the same. We have reversed the 10u and placed the lower diode above the other diode.
The operation of the circuit is completely different.
When the BC547 turns ON, the 10u charges via the top diode. When the transistor turns OFF, the 4k7 pulls the left lead of the 10u towards the positive rail. This pulls the negative lead up and it rises above the 12v rail by about 11v. This puts 12v plus 11v on the left lead of the second diode and it passes this voltage to the 22u. The 22u charges to about 20v.
A practical version of this circuit is in our **50 - 555 Projects** eBook. Battery Charger
A 12v battery can be used to charge another 12v battery by using a voltage doubler circuit and although the full voltage is not required, the circuit automatically adjusts and charges the battery. When the battery is removed, the output voltage rises to about 18-20v.
Circuit C is a **DIODE PUMP** (**VOLTAGE DOUBLER**) from an AC source (such as the "Mains").

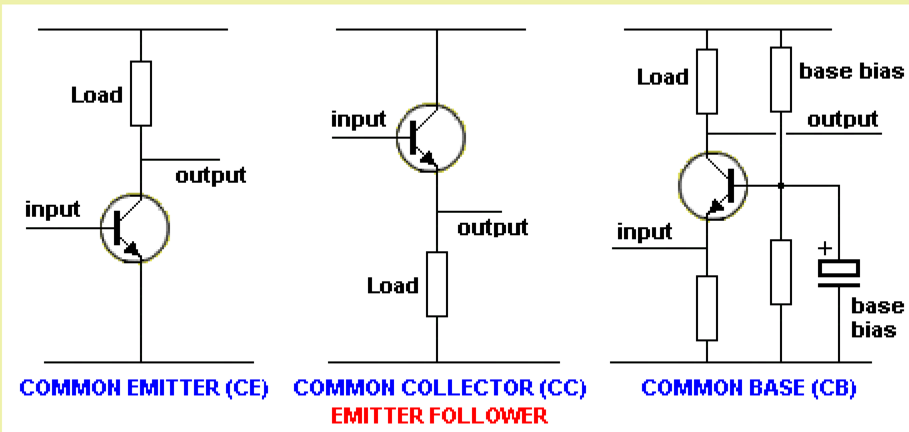


The circuit takes a number of cycles to get up to full output voltage and this is how it works:
The input voltage rises and because the 22u is uncharged, the 10u starts to charge as soon as the 0.6v across the top diode is reached.
The 10u charges to about 10v and puts about 5v on the 22u.
When the AC reverses polarity, the top diode does not have any effect but the lower diode becomes forward biased and it allows the 10u to charge to about 15v.
When the AC reverses again so that the top input becomes positive, the 10u already has 15v on it and the AC adds another 15v.
This means the positive lead of the 10u is 30v above the lower rail and it charges the 22u to about 15v.
This happens a few more times and eventually the 22u gets charged to 30v (minus 2 x 0.6v diode drops).
After 5 or more cycles, the 22u has about 30v across it and the 10u keeps "topping up" the voltage as follows:
Say the 10u has 14v across it, when the top input of the AC becomes negative, the 10u immediately jumps to a position below the 0v rail and the diode connected to the 10u allows it to be charged to 15v, (the top diode effectively comes "out-of-circuit" as shown in diagram D:

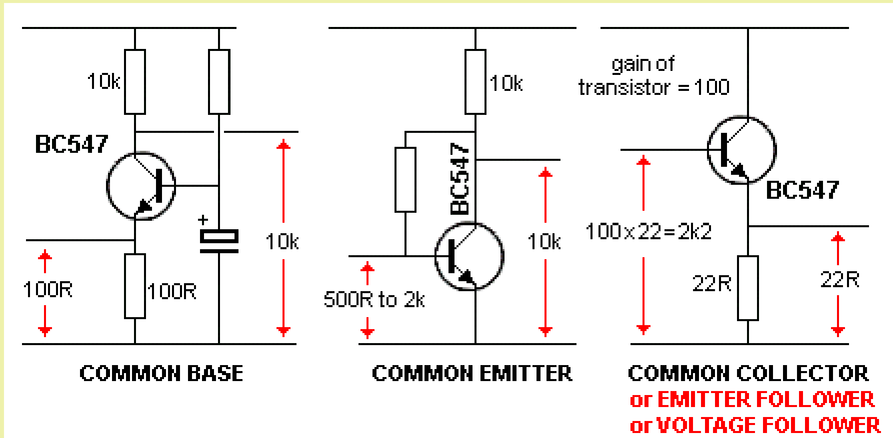


SUMMARY

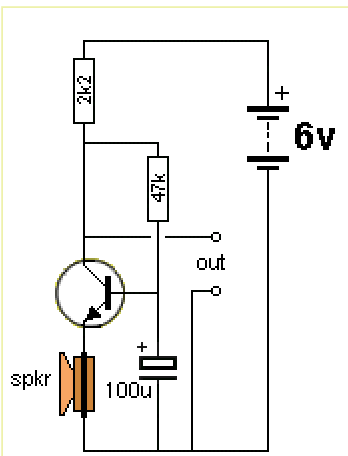
Here is a summary of the features of the three basic ways a transistor can be connected:

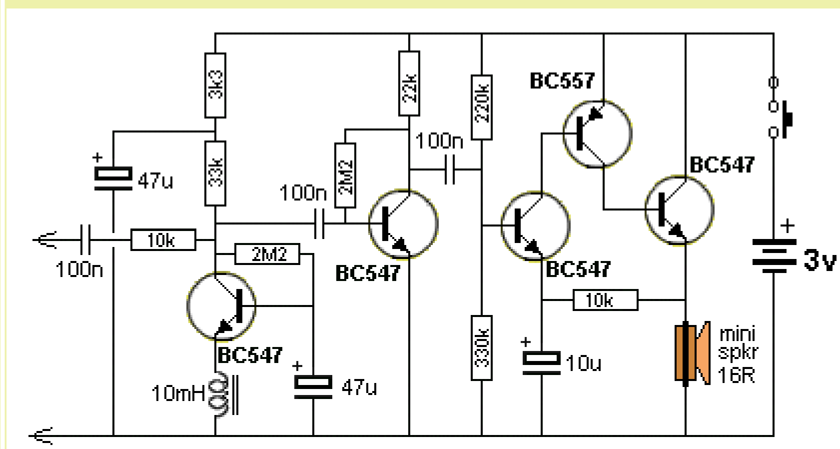


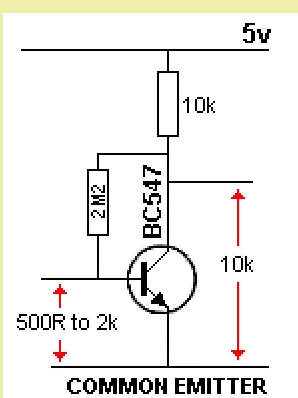
Characteristic	Common Emitter	Common Collector	Common Base
Input Impedance	Medium	High	Low
Output Impedance	High	Low	Very High
Phase Angle	180^o	0^o	0^o
Voltage Gain	Medium	slightly less than 1	High
Current Gain	Medium	High	Low
Power Gain	Very High	Medium	Low



You can see the input impedance of a **COMMON BASE** stage is equal to the resistance of the emitter resistor
it is designed to interface (connect) a low impedance device to the circuit. This is normally very hard to do as the speaker or inductor may be only 8 to 50 ohms. Trying to connect an 8 ohm device to the input of a 500R stage produces a lot of mis-match and produces high losses. The common base arrangement does this very well and that's why it is so useful.





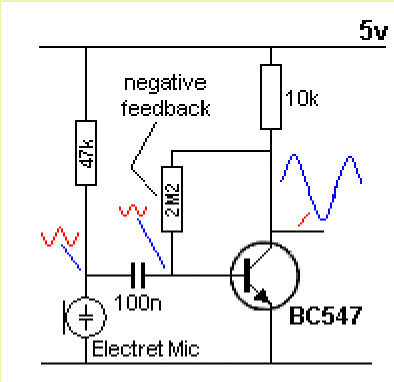


The **COMMON EMITTER** arrangement needs more explanation as the summary above suggests the input impedance is about 500R to 2k.
We have already explained (in **Fig 11**) that a transistor with a gain of 200 will produce a voltage amplification of about 70 in this type of circuit. The reason is the 2M2 base-bias resistor.
It is acting as a feedback resistor and is acting AGAINST the incoming signal.
For example, if the incoming signal is rising, the collector voltage will drop and this will be passed through the base-bias resistor to deliver less current to the base. This is opposing the current being delivered via the signal and that's why it is called NEGATIVE EFFECT or NEGATIVE FEEDBACK. Thus the transistor cannot produce the output amplitude you are expecting.

NOTE:

The value of 500R to 2k2 for the input impedance of a common-emitter stage is very misleading.

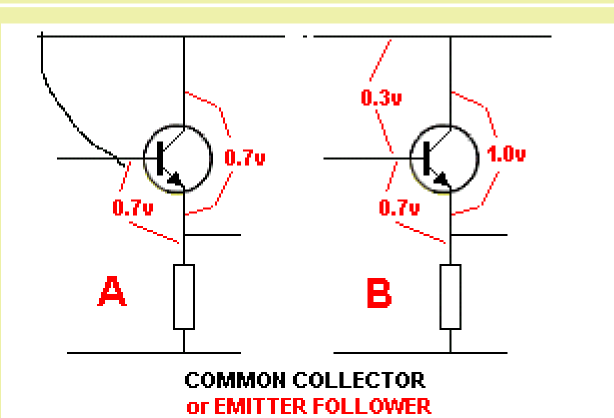
You would think the input is like driving into a 2k2 resistor. But this is not the case. Placing a 2M2 between the base and 5v rail will turn the transistor ON fully. The 2uA via the 2M2 is sufficient to turn the transistor ON. This is obviously nothing like driving into a 2k2 and you should avoid thinking about the input as a low value as it only applies when the transistor is heavily conducting.
Transistors will respond to a fraction of a microamp and you should think of them as having very sensitive inputs.



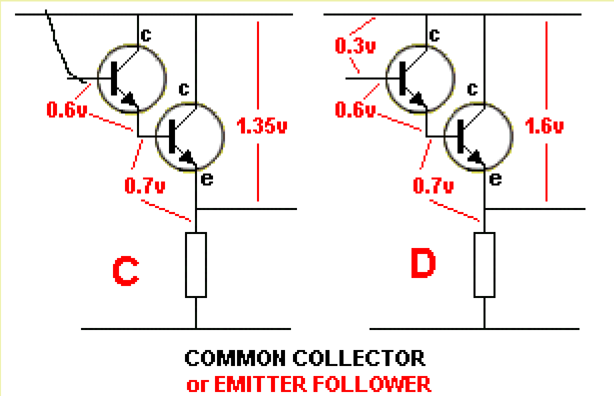
But the question at the moment is this: **What effect does the input impedance have on an incoming signal?**
When a transistor is **lightly loaded**, as shown in the circuit on the left, a very small current into the base will produce an output waveform. It is too complex to talk about input impedance of 500R to 2k. This value does not help us explain the operation when lightly loaded.
The easiest way to talk about the input impedance is to discuss the current entering the base when a signal is applied, by looking at the "voltage waveform". The voltage (signal) on the base can be viewed with a CRO (Cathode ray Oscilloscope) and although we don't know the value of the associated current, the voltage waveforms though the circuit produce an increase of about 70 and this is adequate in most cases.

We see the waveform produced by the electret mic is reduced when it passes through the 100n capacitor.
This reduction is due to the impedance (resistance) of the 100n capacitor and also the input impedance of the transistor. Rather than trying to work out all these complicated values, the easiest way to create the required amplitude on the output of the stage is to reduce the 47k. When this value is reduced, the output of the electret mic increases. Talking Electronics uses only high quality electret mics and they require a load resistor of 33k to 68k for 5v supply. Some junk electret mics need 10k or as low as 2k2 and that's why this resistor can range from 2k2 to 68k.
The electret mic will produce an output of about 30mV and the waveform on the base will be about 20mV. With a gain of 70, the collector waveform will be 1400mV.
When a transistor is required to pass a high collector current, the current entering the base is considerably higher than discussed above. When the collector current is approaching the maximum for the type of transistor, a transistor with a gain of 200 will not produce this high gain. The gain will be considerably LOWER. It may be 100 or 70 or even 50. This is why a high input current is needed and it will appear as though the transistor has a low-to-medium input impedance.

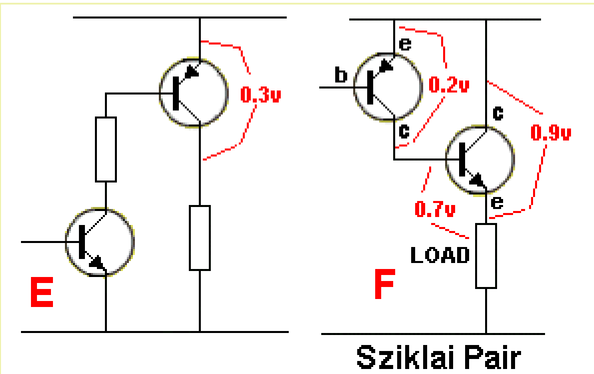
Common-Collector Problems



Designing a **COMMON-COLLECTOR** stage has a number of problems. The main one is the voltage dropped across the collector-emitter terminals of the output transistor.
This transistor is also called an **EMITTER-FOLLOWER** and it is always going to have a minimum voltage-drop of 0.7v when the base is at rail voltage. But in most cases the base will be less than rail voltage by at least 0.3v. This means the voltage across the transistor will be 1v.
A transistor in a common-emitter configuration will be about 0.2v. This means the common-collector arrangement will be 5 times hotter (approx) and the load will get 0.8v less voltage.



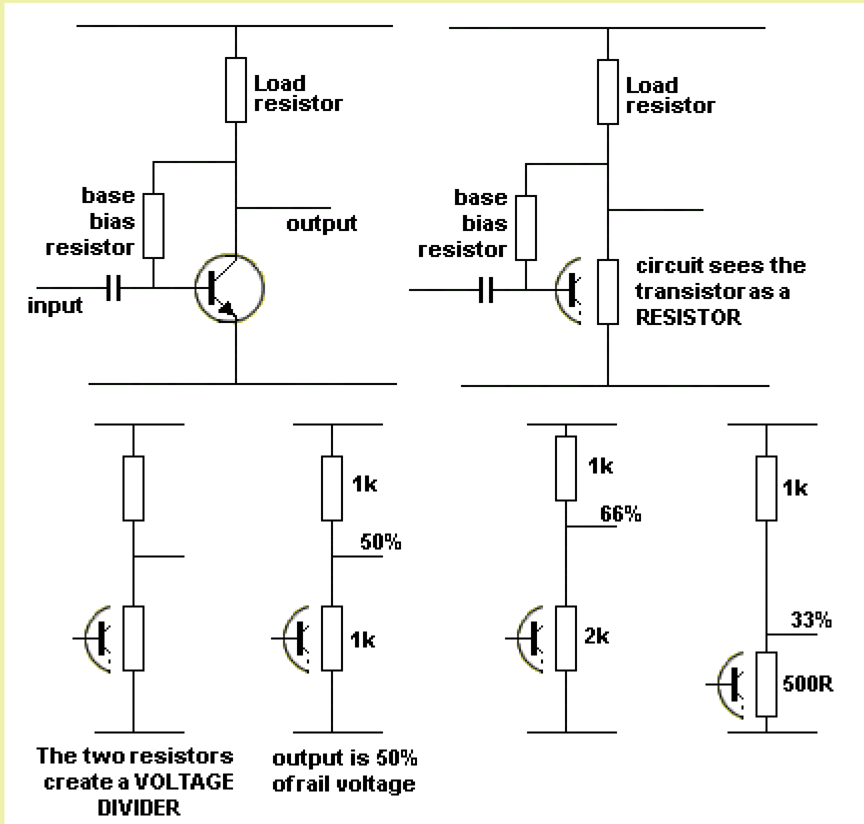
The situation gets worse when a Darlington pair is connected as a common-collector output. The voltage across the two transistors will be a minimum of 1.35v and will normally be **more than** 1.6v.



Figs E and **F** show some solutions to driving a load with the most-efficient design.
Fig E is called a NPN/PNP pair and **Fig F** is a Sziklai Pair.
Only the important voltage-drops have been shown and these values will be higher for some transistors and will also increase as the current increases.
This is just an example of the minimum values to expect.

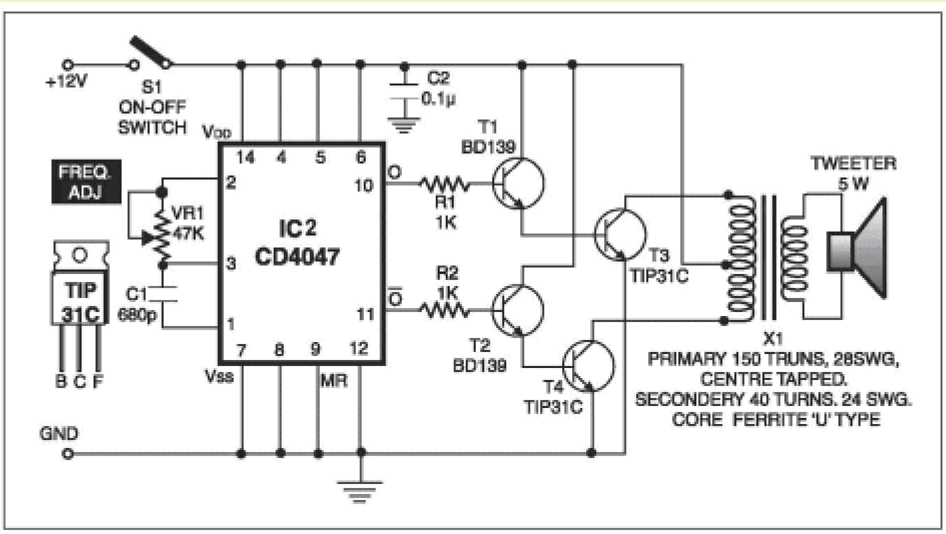
THE TRANSISTOR AS A VARIABLE RESISTOR

Many circuits use a transistor as a variable resistor but this fact is never mentioned.
There are many ways to look at how a transistor is operating and one of them is to see the transistor as a VARIABLE RESISTOR.
In fact, that is what the transistor is doing in 99% of circuits. It is acting as a VARIABLE RESISTOR.
In a digital circuit, the transistor is turning OFF completely then turning ON fully. This is equivalent to a very high-value resistor in the first instance, then a very low-value resistor.
In an audio circuit, the resistance of the transistor is reducing then increasing. It is working in series with a LOAD resistor and the voltage at the join of these two is the OUTPUT of the stage.
For a common-emitter stage, when the resistance of the transistor decreases, the output is LOW (meaning the output voltage is small) and when it increases, the output is HIGH.
The transistor and the load resistor form a VOLTAGE DIVIDER and the voltage at the join of these two components depends on the value of the transistor.
When the resistance of the transistor is equal to the load resistor, the voltage at the join will be 50% of the supply. When the resistance of the transistor is twice, the voltage will be 66% and when it is half, the voltage will be 33%.

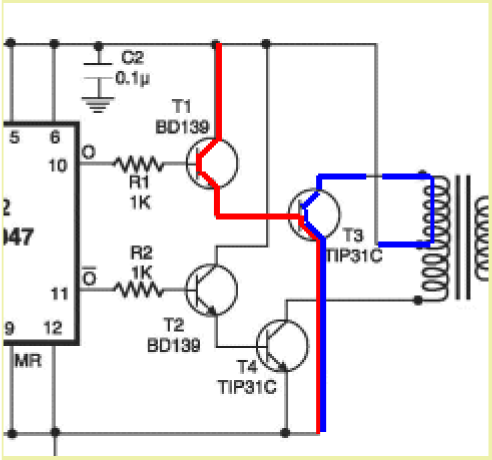


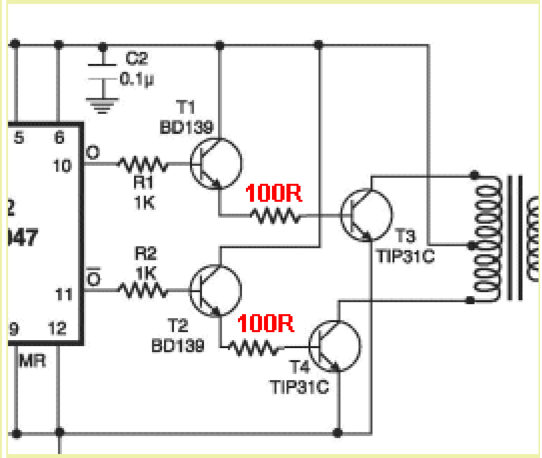
The transistor as a VARIABLE RESISTOR

SHORT CIRCUIT CURRENT / shoot-through current



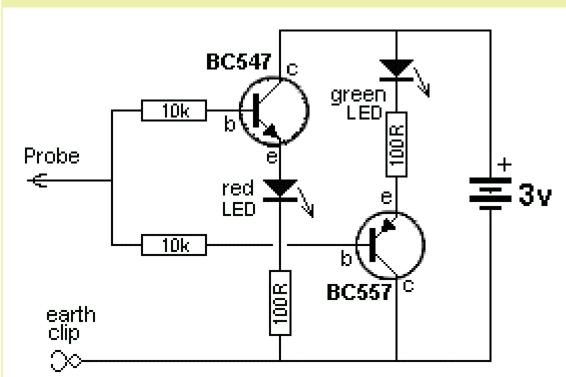
Here is one of the major hidden problems when designing a circuit.
It's called a **SHORT CIRCUIT current** or "**Shoot-through**" current and occurs when two transistors are directly connected together as shown in the output section of the circuit on the left.
The chip can deliver about 10mA to the base of the top transistor and if the transistor has a gain of 100, the collector-emitter current will be 1AMP !!





This current will also flow through the lower transistor and is WASTED CURRENT. It creates an almost SHORT-CIRCUIT across the supply rails.
The solution is to add a low value resistor such as 100R to limit the current.

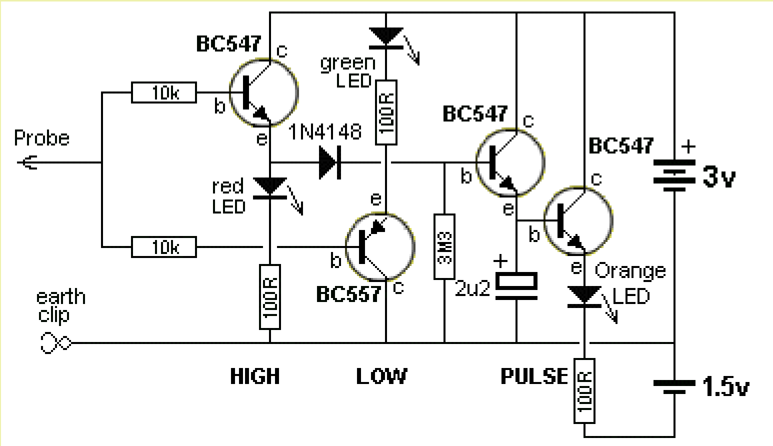
NO CURRENT . . .



No ON-OFF switch needed

In all the circuits we have discussed, there is a small quiescent current flowing when the circuit is "sitting around" doing nothing - called the "Quiescent Current." This current is the biasing current and is needed to turn the transistor(s) ON slightly so it will amplify the smallest signal. If the transistor is not turned on slightly, it will not amplify signals smaller than 600mV as the base must see a signal more than 550mV for the transistor to start to turn on.
The circuit above is a LOGIC PROBE and will detect a HIGH or LOW on a digital circuit where the waveform is higher than 2.5v. This circuit can be in a state of "cut-off" (not conducting) and the input amplitude will turn the circuit ON.
The clever feature of this circuit is the lack of an ON-OFF switch. The circuit takes no current when not detecting a waveform because the voltage-drops across the semiconductor junctions is greater than 3v (and the supply is 3v).
To turn on a transistor, the voltage between the base and emitter must be greater than 550mV. But if the voltage is less than 550mV, absolutely no current flows through the junction.
The same applies with the characteristic voltage of a LED. For a red LED, the characteristic voltage is 1.7v but if the voltage is less than about 1.5v, no current will flow. The same applies to a green LED. Its operating characteristic voltage is 2.1v to 2.3v but when the voltage less than 1.9v, no current will flow.
The current-path for the circuit in "idle mode" is through the green LED (1.9v), 100R, the emitter-base junction of the BC557 (0.55v), through two 10k resistors, the base-emitter junction of the BC547 (0.55v), the red LED (1.5v)100R to the 0v rail.
When the minimum voltages are added we get 4.5v. But the supply is only 3v and thus it is not high enough to meet all the minimum junction voltages.

Thus no current will flow through the circuit when "sitting around."



LOGIC PROBE with HIGH, LOW and PULSE

The same "cut-off" condition applies to the **Logic Probe** circuit above. But this time an orange LED is added to the circuit.
The Pulse LED is connected to the HIGH section of the circuit and its illumination is extended by the inclusion of the 2u2 electrolytic so a brief pulse can be observed.
To extend the illumination of the orange LED, we need to charge this electrolytic.
But an electrolytic needs a lot of current to charge it quickly and the input of a Logic Probe is HIGH IMPEDANCE - in other words it has no "charging capability."
This means the pulse from the input needs a lot of assistance to charge the electrolytic.
To do this we have used 2 transistors. The first and third transistors form a SUPER-ALPHA pair and this provides a lot of "strength" (current) to charge the electro.
But we can only charge a very **small-value** electro, so we need another transistor to ELECTRONICALLY increase the value of the electro about 100 times. That's the purpose of transistor four.
We now have the circuit we need to extend the illumination of the pulse LED.
But when all these components are connected, we have run out of voltage to illuminate the LED with a HIGH of 3v.
To solve this problem we have added a single 1.5v cell as shown in the diagram. The emitter of the 4th transistor will have about 1v on it (with reference to the 0v rail) and the lower lead of the 100R will have minus 1.5v (with reference tot he 0v rail). This means the orange LED and 100R will see a voltage of 2.5v. This is sufficient to illuminate the LED.

THE POWER SUPPLY

We are not going into designing a power supply but want to cover one of the mayor misconceptions about a power supply:
A lot of readers to a Forum have asked: **I want a 20mA power supply, but all I can find is a 100mA supply. Will this BURN-OUT my project?**
Answer: If the project is correctly designed and requires 20mA when connected to a 12v power supply, it will take exactly 20mA and not burn out.
If the project requires 100mA, it can be connected to a 100mA power supply and it will work correctly.
If the project requires 200mA and is connected to a 100mA power supply, the power supply will deliver 100mA (and maybe a little more) but the voltage will start to fall when the full 200mA is required and the power supply will get very hot. The project will not be damaged but it will not perform to its full capability.
See 200 Transistor Circuits: 1-100 101 - 200 for projects on Power Supplies.

CIRCUIT PROBLEMS:

CIRCUIT 1

The input to a microcontroller needs a HIGH when a microphone picks up audio. This is the requirement from a customer. The circuit in **Fig 104** was designed to meet the customers requirements. The 10mV audio waveform from a microphone is converted to a 4v-5v CONSTANT HIGH. The following circuit is the result:

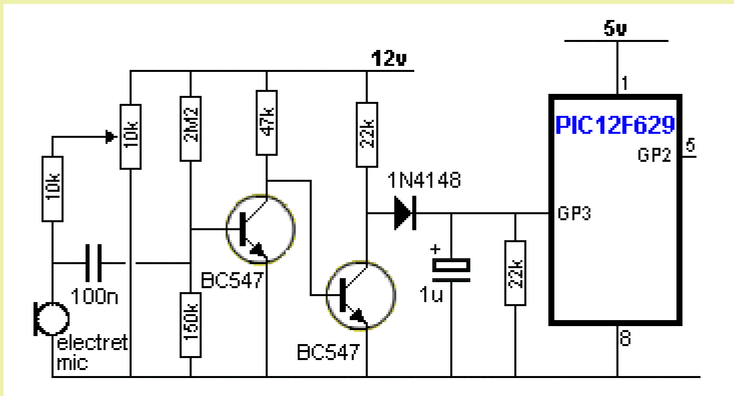


Fig 104.

The starting point is to bias the first transistor so the voltage on the base is just at the point of turning it ON.
This allows the 47k resistor to turn on the second transistor and the diode does not see any voltage.
This means the 1u does not get charged and the input to the microcontroller sees a LOW.
This is called the QUIESCENT (standing, stand-by or idle) condition.
The gain of the electret microphone is adjusted by the 10k pot and when it receives a loud audio signal it produces an output of about 20mV.
This signal is sufficient to turn ON the first transistor and turn OFF the second transistor so that signal diode sees a HIGH pulse via the 4k7.
This voltage is passed to the 1u and it gradually gets charged. When the voltage on the 1u reaches about 4-5v, the microcontroller sees a HIGH and the program in the micro produces an output.

CIRCUIT **2**

How does this amplifier get biased?:

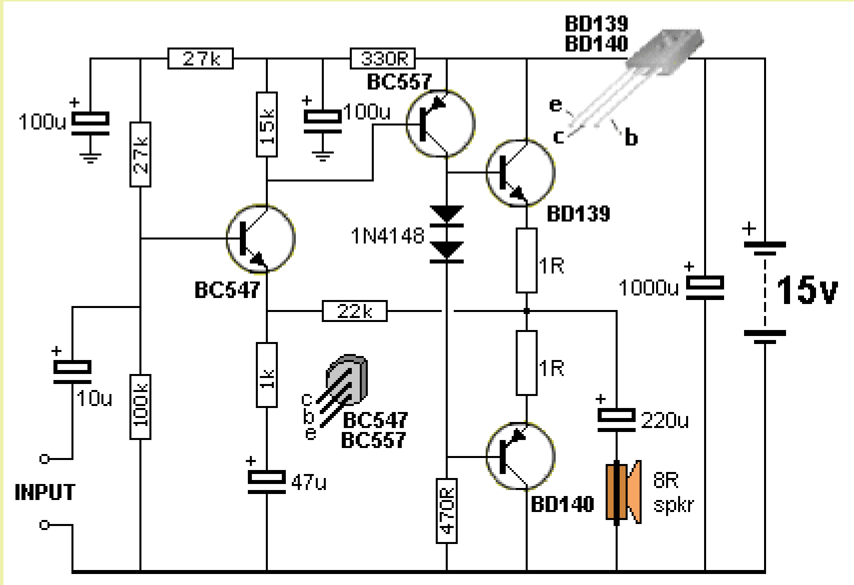


Fig 105.

One of the most difficult amplifiers to design and service is a DC (Directly-Coupled) amplifier. The voltage on the output is fed back to the input to create the idle (quiescent) state and the biasing of the input is created from the output. So, where do you start?
All the facts we have learnt in this discussion are needed to understand how this circuit works.
The circuit has high gain and without the 22k feedback, we would not be able to create an output "set-point." The first transistor has no DC voltage gain as but it does have an AC voltage gain of about 22. The BC557 provides a voltage gain of about 70-100 and the output transistors only provide a current gain. This gives the circuit a voltage gain of about 2,000. A 50mV input will produce an output of about 10v.
The aim is to get the output voltage near to mid-rail so it can swing both positive and negative and create a relatively distortion-less waveform.
The starting point is the voltage divider made up of the 27k + 27k and 100k. This puts 10v on the base of the first transistor.
Now we come to the 470R resistor on the base of the BD140 transistor. This resistor is a very low value and is keeping the BD140 turned ON and the emitter voltage will be very small.
Here's the interesting part: The collector of the BC557 can pull the base of the BD140 UP without any difficulty to about 1.4v less than the positive rail, due to the two 1N4148 diodes.

The Two Biasing Diodes
These two diodes prevent both output transistors turning ON at the same time. If the transistors are both turned ON at any point in the cycle, a very high current will flow and create a short-circuit.
How do the diodes work?
Let's remove the diodes and see what happens.
The

and also due to the base-emitter voltage-drops across the two output transistors. But this only raises the collector **about 1.4v**.
To be able to pull higher, the transistor must turn on harder and since the bottom transistor is being pulled down by 470R, the top transistor is also being pulled down via the two 1R resistors. The BC557 sees the base of the BD139 as a 470R resistor, plus the actual 470R resistor. This make it 220R.
To raise the voltage on the base of the BD140, requires current through the 470R and the BC557 needs to be turned on a certain amount to provide current through the 470R and into the base of the BD139 AT THE SAME TIME.

At the moment the join of the two one-ohm resistors has a very low voltage on it and the BC547 is also an emitter-follower and the emitter is about 10v minus 0.7v.
This puts a current through the 22k resistor of less than 1mA however this current also flows through the emitter-base junction of the BC557 and if the transistor has a gain of 100, the emitter-collector current can be as high as 100mA.
However the 220R (470R and 470R in parallel) resistor only needs a flow of 22mA to create a voltage of 5v across it, so we have plenty of gain to begin to turn on the circuit.
The BC557 creates a current-flow through the 470R and the BD140 starts to get pulled UP. This puts less current though the BC547 and less current through the base of the BC557, so the BC557 starts to turn off.
The actual settling-point has a lot to do with the 27k + 27k and 100k base-bias resistors as this puts 10v on the base and the emitter 9.3v. Suppose the output settles at 7.5v. This puts 1.8v across the 22k and creates a current-flow through this resistor. Approximately the same current flows through the emitter-base of the BC557 and about 100 times this current is available to be divided between the 470R and base of the BD139. This is how the output becomes biased at very nearly half-rail voltage.

CIRCUIT 3

Select the best circuit between Figs 106 and 107:

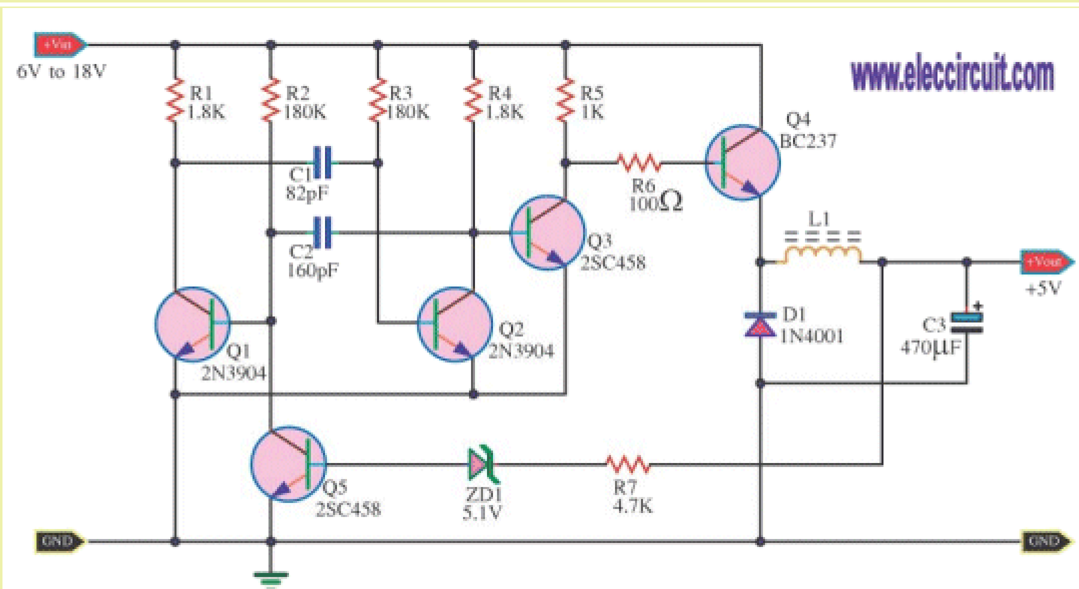


Fig 106.

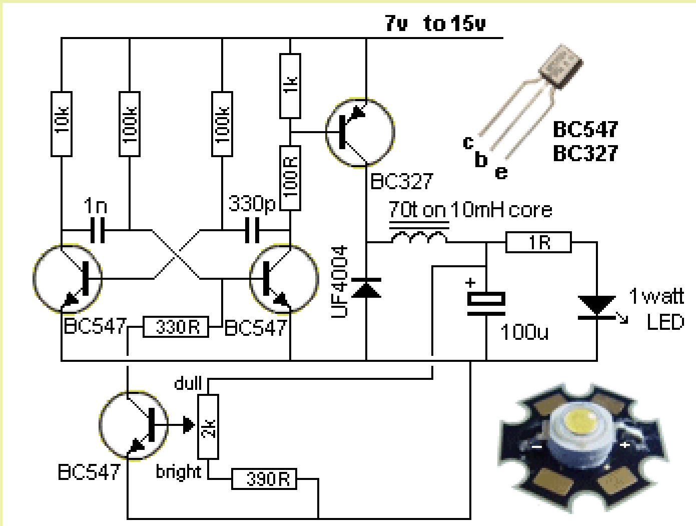


Fig 107.

From the theory discussed above, can you see the problem with driving the BC237 in **Fig106**.
It is being pulled HIGH via the 1k resistor. If the transistor has a gain of 100, Q4 will effectively be equal to a 10 ohm resistor. For 100mA current delivered to the output, 1v will be dropped across this transistor and it will start to get hot. This is wasted energy.
A BC237is only capable of delivering 100mA.

Fig 106 has been re-drawn as **Fig 107** with improvements and corrections.
The output transistor has been changed to a BC327. It will handle 800mA.
A 1N4001 is not a high-speed diode and using an Ultra Fast 4004 will deliver an extra 50mA to the output.
See: 200 Transistor Circuits for details.

CIRCUIT 4

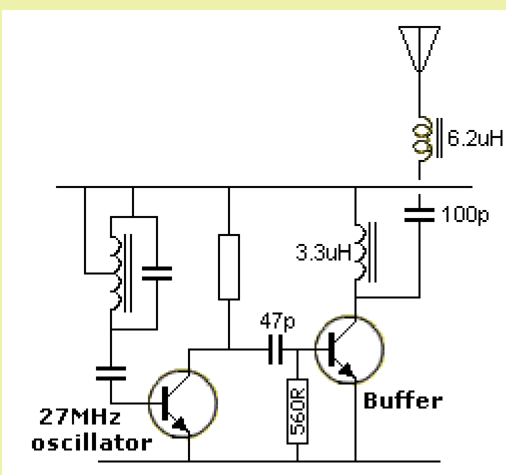


Fig 107a.

Fig107a shows a 560R resistor to discharge the 47p coupling-capacitor.
The circuit is a 27MHz transmitter with buffer. The buffer is an amplifying stage to increase the output.
You will notice two things: the buffer stage is not biased ON and a low value resistor is connected between base and 0v rail. This called a "Class-C" stage.
This resistor discharges the capacitor so it will transfer the maximum amount of energy (on each cycle), from the oscillator stage to the output stage.
The resistor is not needed when charging the capacitor but it is very important to discharge the capacitor.
Remove the resistor and the output will be nearly ZERO!

Another point to note with a **"Class-C" stage** is this:
All the energy to turn-on the Buffer stage comes from the coupling capacitor.

CIRCUIT 5

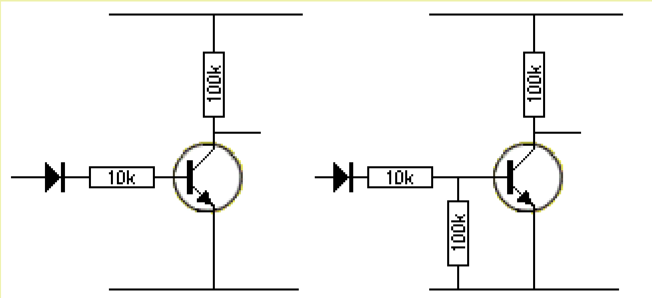
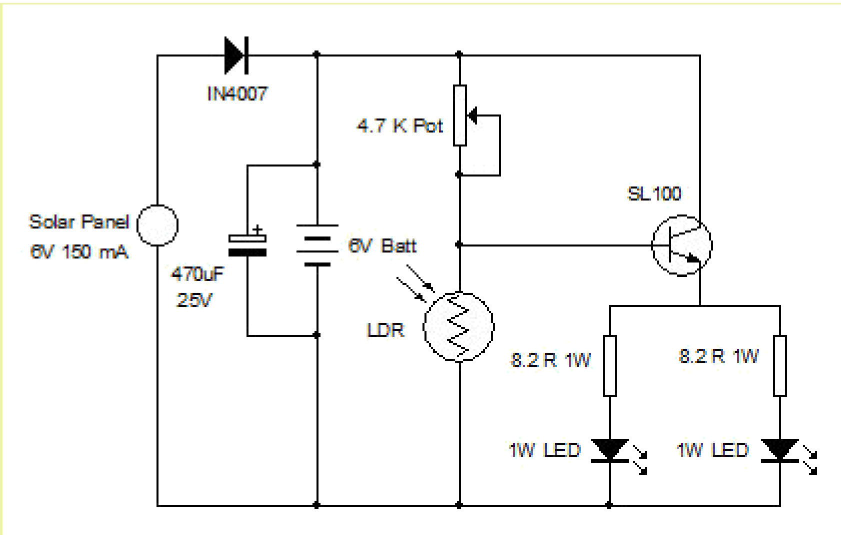


Fig 107b.

The high-value collector load also gives the transistor in the first circuit a high possibility to pick up noise on the base and produce pulses on the collector.

Fig107b shows a transistor that is turned on via a diode on the base.
This is a BAD design. The transistor is said to be in a HIGH IMPEDANCE STATE, when not turned ON.
This means the base is FLOATING when the anode end of the diode is at 0v.
When the anode of the diode is LOW, it does not deliver any voltage to the base and the effective resistance on the base is infinite and any noise picked up by the base will turn the transistor ON. To prevent this from happening, a 100k resistor is connected between base and 0v rail.

CIRCUIT 6

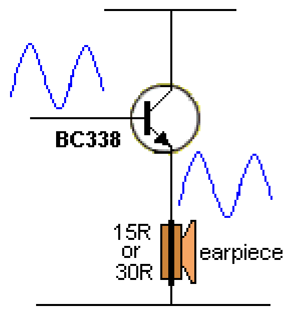


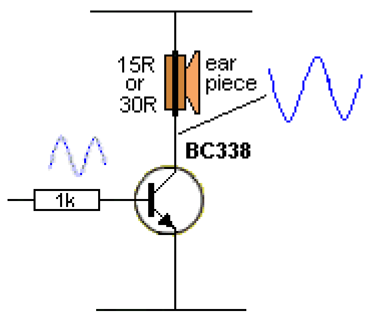
Solar Night Light

Here is a poorly-designed circuit.
A 1 watt white LED has a characteristic voltage of 3.2v to 3.6v and it takes 300mA. The voltage drop across 8R3 will be V=IR =.3 x 8.2 = 2.46v The base voltage will be 3.2 + 2.46 + 0.7 = 6.36v
The LEDs will not turn on very brightly. A white LED will start to turn on at a lower voltage but the full brightness is not achieved until 300mA is flowing and this will produce a voltage of about 3.2 to 3.6v across the LED.
There is another major fault with the circuit.
The transistor is only designed to pass 500mA. It is over-stressed. The base current will be about 20mA to 40mA. This current must be supplied by the 4k7 pot.
This current is too much for a pot.
Secondly, the current must flow through the LDR when it receives illumination, so that the current is removed from the base of the transistor. This current is too high for the LDR.
You can learn a lot from other designer's mistakes.

CIRCUIT 7

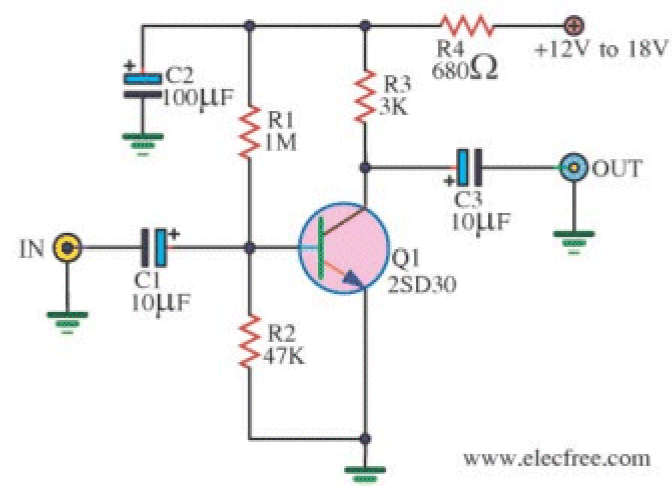
Anil wanted to increase the volume from his mobile handset using a single transistor and a few components.

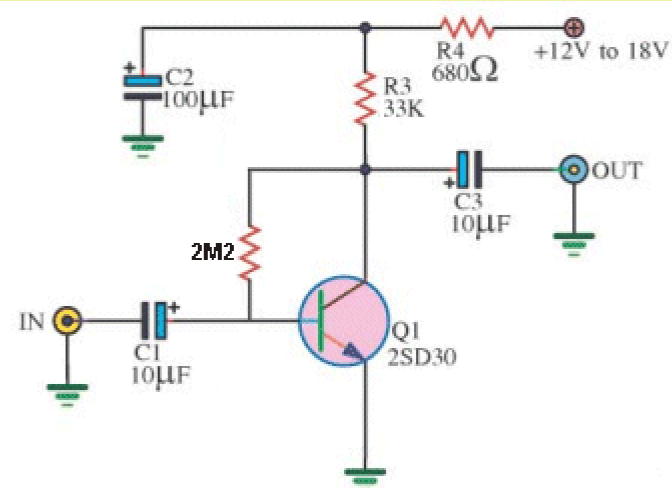




He has a choice of using an emitter-follower or common-emitter amplifier, as shown in the two circuits.
The first circuit will only increase the current.
The second circuit will increase the current AND the voltage of the waveform and is the best circuit to use.

CIRCUIT 8





This circuit is a "semi-bridge-configuration. But it does not have an emitter resistor. The emitter resistor allows the stage to self-adjust the current through the collector-emitter of the transistor to produce an approximate mid-rail voltage on the collector.
Without this resistor it is very difficult to produce mid-rail voltage when the supply rail can vary from 12v to 18v and the gain of the transistor can be anything from 100 to 300.

The solution is to change the biasing to SELF BIAS.
This involves a resistor from collector to emitter. The stage will now have a voltage on the collector and by testing a number of transistors, you can determine the correct value for the base resistor.

There is one other fault with the circuit. The load resistor (3k) is too low.
The circuit is a pre-amplifier and if the collector resistor is increased to 33k, the output signal will be increased 10 times.
It works like this: The incoming signal supplies a small current and this is amplified by the transistor (about 100 times) to produce a current in the collector-emitter circuit. This current flows through the collector-load-resistor and produces a voltage across it. If the resistor is a high value, the voltage produced is high and thus the waveform is high and thus the stage produces a HIGH GAIN.

LAB ELECTRONICS

Lab Electronics produces a "stand-alone" trainer that covers the **common-base**, **common-emitter** and **common-collector** stages:

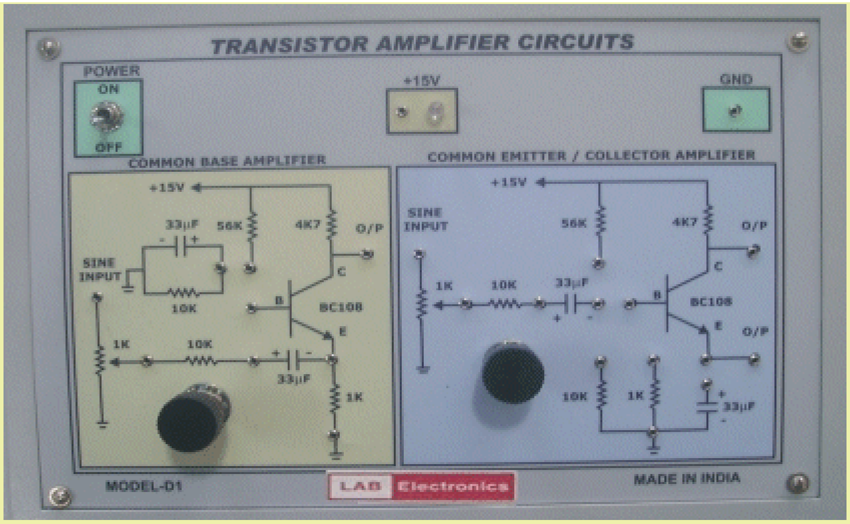


Fig 108.

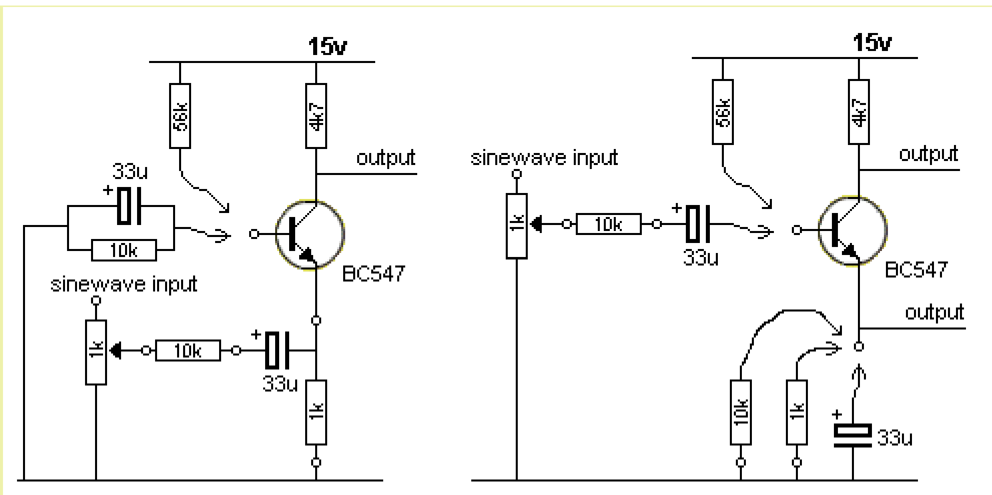


Fig 109.

Fig 109 shows the circuit for the trainer and how it can be wired to produce all the stages we have covered in this discussion. By feeding each stage with a sinewave at the input, you can view the output on a CRO and see how it works. This is only part of the picture to understanding the operation of each stage as the input and output impedances are also important and the third important thing is the effect of the capacitor(s) and/or electrolytics that connect one stage to another and/or those connected to the emitter to provide EMITTER BY-PASS.

We have already explained the advantage of a common-base stage (to connect a very low impedance device to an amplifying circuit) and the advantage of a common-collector (emitter-follower) circuit to drive a low-impedance load. e load.

A "trainer" only provides a fraction of the knowledge needed to understand "circuit-design" - but it helps. You must build "real-life" circuits to get a complete understanding.

The trainer above has lots of faults in its design. You cannot get a full understand of the common-base stage with 1k in the emitter. It should be 100R or less. The 10k feeding the 33u will attenuate the sinewave and is not needed.

The common-emitter stage does not provide any self-biasing option. The 56k base-bias is too low and the collector and emitters resistors are the wrong values to get any appreciable gain from the stage. When the 33u is put across the emitter resistor, the gain will increase enormously.

It would be much better to work on the circuits we have presented above and view the output on a

CRO.
This trainer does not give you a full understanding of the operation of the three stages. (33u and 15v is rarely used in modern designs), I would give it a MISS.

Fig 110.

Fig 110 shows another trainer. It covers the common-emitter stage.
When a common-emitter stage drives a transformer or speaker as a load in the collector circuit, we want the sound to be free of distortion and to do this this we must bias the stage so the collector is at half-rail voltage when no audio is present.
This allows the transistor to turn ON and OFF to provide the maximum voltage-swing. If the transistor is not sitting at mid-rail, either the positive or the negative peaks of the signal will hit either the positive or negative rail and produce distortion - because the full excursion (height) will not be reproduced.
But biasing the transistor at mid-rail means the current though the speaker or transformer will be about half the peak current and this is wasted as it flows at all times, even when audio is not being processed.
That's why this type of stage is not efficient and it heats up the output transistor considerably, even with no audio.
This type of circuit is called "CLASS-A" and the trainer above has a "Bridge" circuit as a pre-amplifier and is capacitor-coupled to a common-emitter stage as an output stage - driving a transformer - as a class "A" amplifier. Since transformers are expensive, difficult to purchase and add weight to a project, they have generally been replaced by complementary-symmetry push-pull class-B output stages.
All the features in this trainer have been covered in the circuits above.

Which circuit is best?

Fig 111 shows four different circuits driving a speaker. Which circuit is best??

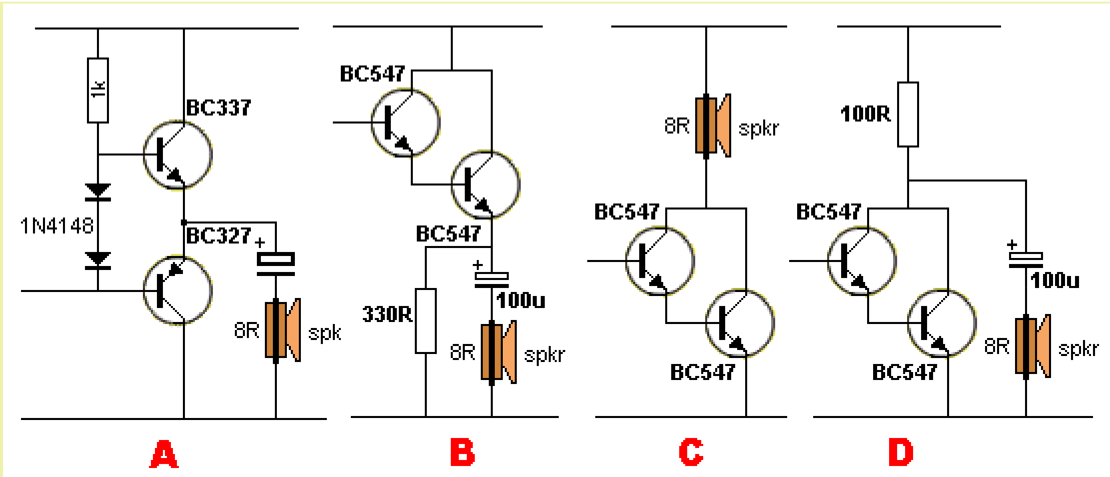


Fig 111.

The 4 circuits in **Fig 111** drive an 8 ohm speaker and are called **OUTPUT STAGES** or **DRIVER STAGES.** They are all different in performance and have different input voltage requirements.
Circuit A is really only a one transistor emitter-follower amplifier as the other transistor discharges the electrolytic.
However it is fully discharged and represents only a few ohms resistance (impedance) in series with the speaker. The input voltage-swing must be as large as possible (called rail-to-rail swing) to achieve the maximum output.
Circuit B is a two-transistor amplifier (called a **Darlington Pair**) and requires only a very small input current for the circuit to work, but a rail-to-rail voltage-swing. The speaker is AC coupled and only the audio current enters the cone and the cone is not displaced by any DC current. However the 100u is discharged via a 330R and the electrolytic is equivalent to a 330R in series with the speaker. The output from this circuit will be very low.
Circuit C is a **Darlington Pair** directly connected to a speaker. The input is very sensitive and requires less than 1v swing for full output. However DC flows through the speaker and will heat up the coil as well as shift the cone and maybe reduce the output capabilities of the speaker. The BC547 driver transistor will not be able to deliver much current. A BC337 is a better choice.
Circuit D is a high gain **Darlington stage** and has a sensitive input and requires less than 1v for full output. However the electrolytic is discharged via a 100R and this means it is equivalent to a 100R in series with the speaker.
The best circuit is "**A**" but it needs a pre-driver transistor to achieve the gain (amplification) of the other 3 circuits.

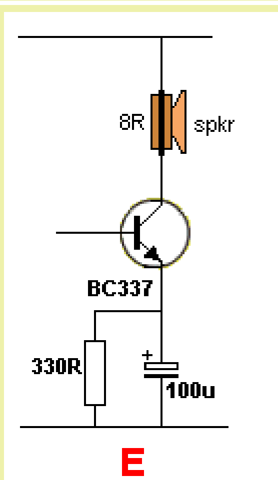


Fig 111a is a "Class-A amplifier" with an emitter resistor that is by-passed with a 100u capacitor. The quiescent (idle) current taken by the stage will be low due to the 330R emitter resistor but when a signal is delivered to the base, the transistor will operate as if the emitter is connected directly to the 0v rail. This means the stage will provide very good amplification while the quiescent current is quite low.
Note: **Fig111a** needs to have a base-bias resistor and a capacitor coupling the base to the previous stage, to qualify as a class-A amplifier. If the base-bias resistor is removed, the stage becomes "Class-C" where the stage uses the energy from the previous stage (via the capacitor) to "turn it on."

Fig 111a.

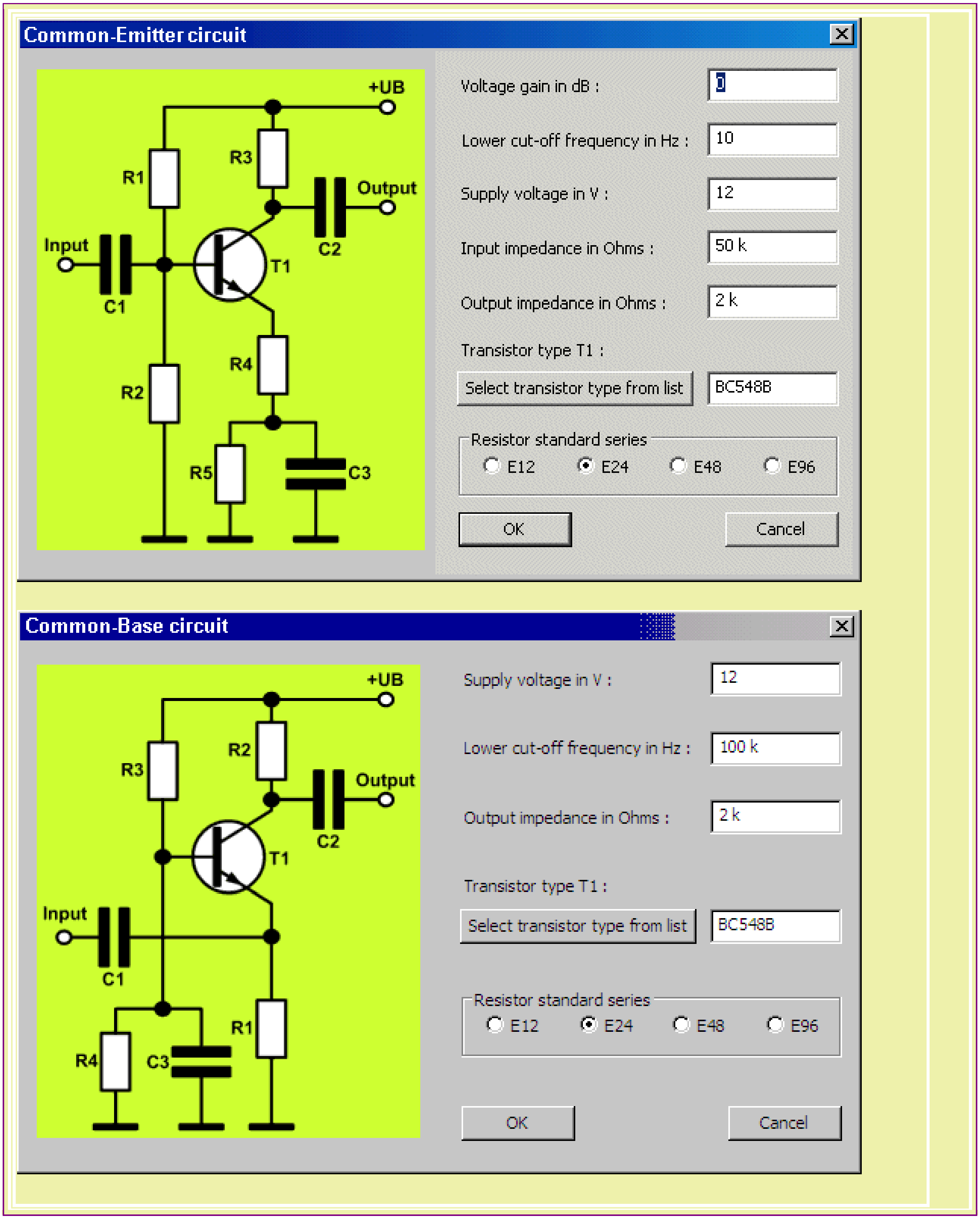
Here is a text book containing a series of questions and answers.:
Self Teaching Guide
I have included it to show you that even electronics authors who have been in electronics for decades, make mistakes.
See the question on base and collector current for a 24v globe. The author has made no mention of the fact that the globe takes 6 times more current when turning ON. That's why you will find the circuit he designed, will not work.
He also describes a two transistor circuit where one transistor turns the other off. This is a very current-wasteful circuit.
He also describes the bleed current for the base (voltage-divider) for a circuit that does not need a voltage divider.

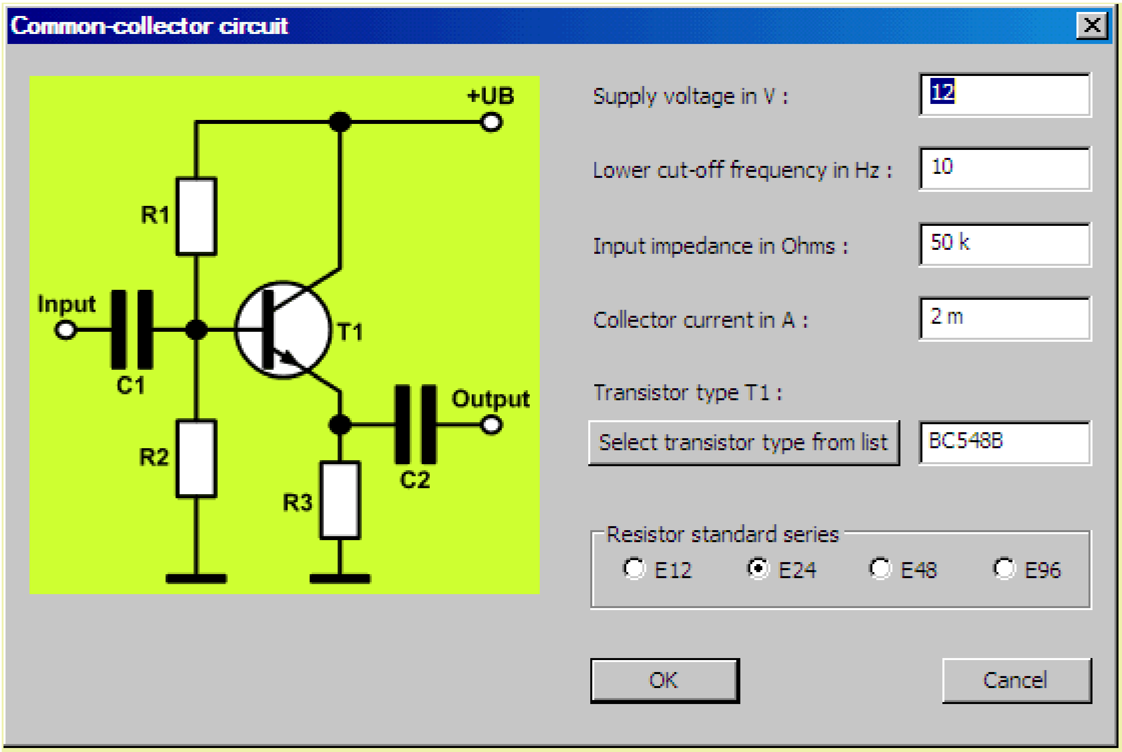
TransistorAmp software by Didaktik Software

The following software allows you to design your own single-stage Common-Emitter, Common-Base or Common-Collector amplifier.
It has been created by **Didaktik Software**. This is version 1.1.1 created 23-6-2012
Download: **TransistorAmp** (.zip 520KB)
TransistorAmp unzips to TransistorAmp.msi (620KB) and will install on your computer with a desktop icon.
Or you can download: **TransistorAmp (.exe)** or **TransistorAmp (.rar)** Unzip .rar in a folder "TransistorAmp" and it will create TransistorAmp.exe Click on the file and the image above will appear.

How to use the software TransistorAmp

TransistorAmp is very easy to use. You start every design with the menu item: "**New Amplifier**". In the pull-down-menu you choose your desired circuit. You can choose between common-base-circuit, common-emitter-circuit and common-collector-circuit. After that you get a dialog, where you have to put in all parameters of your amplifier.
The following 3 images show the layout of the circuit you will produce:


Common-Emitter circuit
+UB
R1
R3
Output
Input
C1
C2
T1
R2
R4
R5
C3
Voltage gain in dB :
0
Lower cut-off frequency in Hz :
10
Supply voltage in V :
12
Input impedance in Ohms :
50 k
Output impedance in Ohms :
2 k
Transistor type T1 :
Select transistor type from list
BC548B
Resistor standard series
E12
E24
E48
E96
OK
Cancel
Common-Base circuit
+UB
R3
R2
Output
T1
C2
Input
C1
R4
C3
R1
Supply voltage in V :
12
Lower cut-off frequency in Hz :
100 k
Output impedance in Ohms :
2 k
Transistor type T1 :
Select transistor type from list
BC548B
Resistor standard series
E12
E24
E48
E96
OK
Cancel



For the selection of the transistor-type you can click on the button: "Select transistor type from ", and you will see a list of all supported transistor types. TransistorAmp supports some thousand transistor types - even some Germanium transistors. Select your desired transistor type and click OK. The selected transistor type will be displayed in the dialog. Both NPN and PNP transistors are supported.

When you have completed your input in the dialog, click OK and see the result. You see a window with your input data, the circuit, the component values and the most important parameters of the operation point. If you want to change your design, you only need to click again on "New Amplifier" and the circuit in the pull-down-menu. Your previous input data will be restored in the input dialog and you can change one or more parameters.ameters.

Note: for the Common-Collector amplifier: "Collector current in A" means: "Collector current in Amps." For 2mA, insert 0.002 etc.

Decibel (dB) Calculator

Decibels are defined as ten times the log of a power ratio. This calculator converts between decibels, voltage gain (or current), and power gain. Just fill in one field and the calculator will convert the other two fields.

$dB= 20\log(V1/V2)= 10\log(P1/P2)$

Decibels (dB)	Voltage Gain	Power Gain

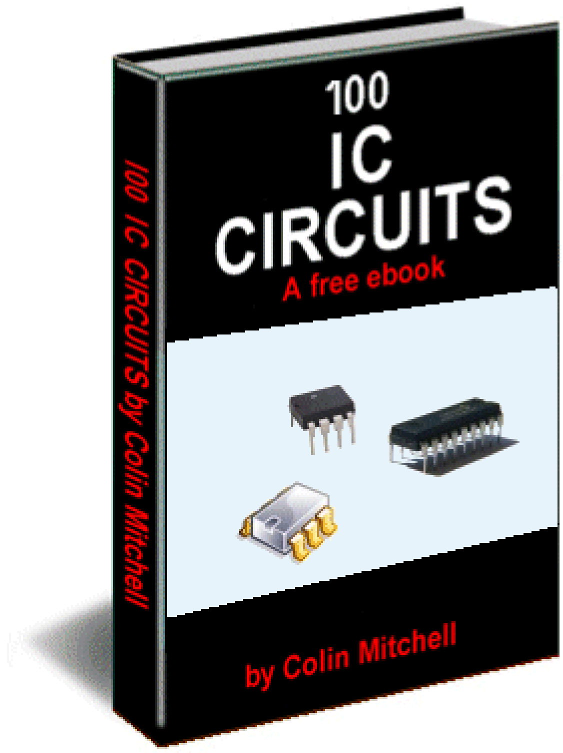
When you are satisfied with the result, click on: "Result - Save". TransistorAmp saves all data in the result window to an HTML-file. You can open this file with a browser (e.g. Firefox or Internet Explorer), inspect it and print it.

Comment from a FORUM MEMBER (http://www.electro-tech-online.com/)
My boss once said to me: "The transistor will never "take-off" it is only equal to a triode (valve)."

You can also learn a lot from our other eBook "200 Transistor Circuits." It is available in two parts:
1- 100 Transistor Circuits
101 - 200 Transistor Circuits
We also have 12 pages of circuits with faults:
Spot the Mistake: P1 P2 P3 P4 .... P9 P10 P11 P12

On the next page we cover connecting a "normal" or "standard or "common transistor" - called Bipolar Junction Transistor (BJT) to a Field Effect Transistor (FET).

P3



For our other three free eBooks,
Go to: 1 - 100 Transistor Circuits
Go to: 101 - 200 Transistor Circuits
Go to: 50 - 555 Circuits

Talking Electronics

See TALKING ELECTRONICS WEBSITE

email Colin Mitchell: talking@tpg.com.au

INTRODUCTION

This is the third part of our **Circuits** e-book series. It contains a further 100 circuits. This time we have concentrated on circuits containing one or more IC's. It's amazing what you can do with transistors but when Integrated Circuits came along, the whole field of electronics exploded.
IC's can handle both analogue as well as digital signals but before their arrival, nearly all circuits were analogue or very simple "digital" switching circuits.

Let's explain what we mean.
The word analogue is a waveform or signal that is changing (increasing and decreasing) at a constant or non constant rate. Examples are voice, music, tones, sounds and frequencies. Equipment such as radios, TV's and amplifiers process analogue signals.
Then digital came along.
Digital is similar to a switch turning something on and off.
The advantage of digital is two-fold.
Firstly it is a very reliable and accurate way to send a signal. The signal is either HIGH or LOW (ON or OFF). It cannot be half-on or one quarter-off.
And secondly, a circuit that is ON, consumes the least amount of energy in the controlling device. In other words, a transistor that is fully turned ON and driving a motor, dissipates the least amount of heat. If it is slightly turned ON or nearly fully turned ON, it gets very hot.
And obviously a transistor that is not turned on at all will consume no energy.
A transistor that turns ON fully and OFF fully is called a SWITCH.
When two transistors are cross-coupled in the form of a flip flop, any pulses entering the circuit cause it to flip and flop and the output goes HIGH on every second pulse. This means the circuit halves the input pulses and is the basis of counting or dividing. It is also the basis of a "Memory Cell" as will will hold a piece of information.
Digital circuits also introduce the concept of two inputs creating a HIGH output when both are HIGH and variations of this.
This is called "logic" and introduces terms such as "Boolean algebra" (Boolean logic) and "gates."
Integrated Circuits started with a few transistors in each "chip" and increased to mini or micro computers in a single chip. These chips are called Microcontrollers and a single chip with a few surrounding components can be programmed to play games, monitor heart-rate and do all sorts of amazing things. Because they can process information at high speed, the end result can appear to have intelligence and this is where we are heading: **AI** (Artificial Intelligence).

In this **IC Circuits ebook**, we have presented about 100 interesting circuits using Integrated Circuits.
In most cases the IC will contain 10 - 100 transistors, cost less than the individual components and take up much less board-space. They also save a lot of circuit designing and quite often consume less current than discrete components or the components they replace.
In all, they are a fantastic way to get something working with the least componentry.
A list of of some of the most common Integrated Circuits (Chips) is provided at the end of this book to help you identify the pins and show you what is inside the chip.
Some of the circuits are available from Talking Electronics as a kit, but others will have to be purchased as individual components from your local electronics store. Electronics is such an enormous field that we cannot provide kits for everything. But if you have a query about one of the circuits, you can contact me.

Colin Mitchell
TALKING ELECTRONICS.
talking@tpg.com.au

To save space we have not provided lengthy explanations of how the circuits work. This has already been covered in TALKING ELECTRONICS Basic Electronics Course, and can be obtained on a CD for $10.00 (posted to anywhere in the world) See Talking Electronics website for more details:
http://www.talkingelectronics.com

MORE INTRO

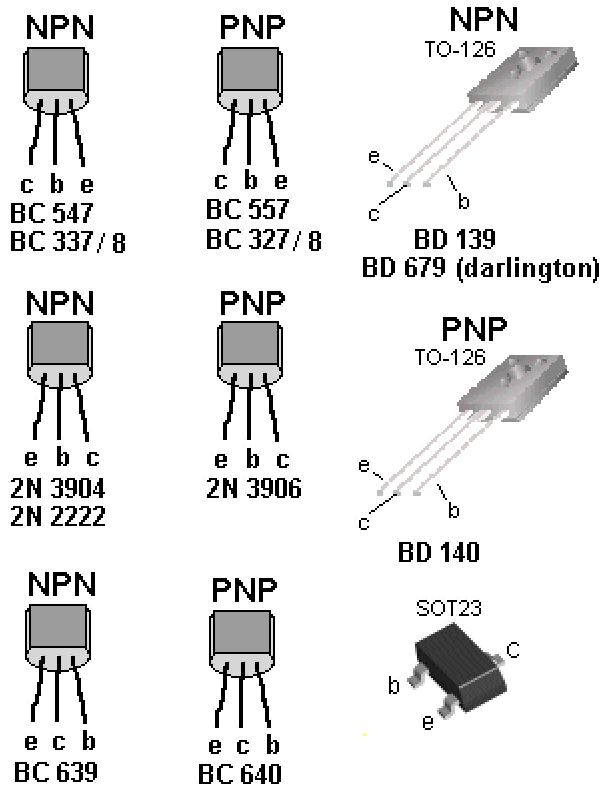
We have said this before abut we will say it again: **There are two ways to learn electronics.**

One is to go to school and study theory for 4 years and come out with all the theoretical knowledge in the world but very little practical experience. The other is to "learn on the job."
I am not saying one approach is better than the other but most electronics enthusiasts are not "book worms" and many have been dissuaded from entering electronics due to the complex mathematics surrounding University-type courses.
Our method is to get around this by advocating designing, building, constructions and even more assembly with lots of experimenting and when you get stuck with a mathematical problem, get some advice or read about it via the thousands of free test books on the web.
Anyone can succeed in this field by applying themselves to constructing projects. You actually learn 10 times faster by doing it yourself and we have had lots of examples of designs from students in the early stages of their career.
And don't think the experts get it right the first time. Look at all the recalled electronics equipment from the early days.
The most amazing inventions have come from almost "newcomers" as evidenced by looking through the "New Inventions" website.
All you have to do is see a path for your ideas and have a goal that you can add your ideas to the "Word of Invention" and you succeed.
Nothing succeeds like success. And if you have a flair for designing things, electronics will provide you a comfortable living for the rest of your life.
The market is very narrow but new designs are coming along all the time and new devices are constantly being invented and more are always needed.
Once you get past this eBook of "Chips" you will want to investigate microcontrollers and this is when your options will explode.
You will be able to carry out tasks you never thought possible, with a chip as small as 8 pins and a few hundred lines of code.
In two weeks you can start to understand the programming code for a microcontroller and perform simple tasks such as flashing a LED and produce sounds and outputs via the press of a button.
All these things are covered on Talking Electronics website and you don't have to buy any books or publications. Everything is available on the web and it is instantly accessible. That's the beauty of the web.
Don't think things are greener on the other side of the fence, by buying a text book. They aren't. Everything you need is on the web AT NO COST.
The only thing you have to do is build things. If you have any technical problem at all, simply email Colin Mitchell and any question will be answered. Nothing could be simpler and this way we guarantee you SUCCESS. Hundreds of readers have already emailed and after 5 or more emails, their circuit works. That's the way we work. One thing at a time and eventually the fault is found.
If you think a circuit will work the first time it is turned on, you are fooling yourself.
All circuits need corrections and improvements and that's what makes a good electronics person. Don't give up. How do you think all the circuits in these eBooks were designed? Some were copied and some were designed from scratch but all had to be built and adjusted slightly to make sure they worked perfectly.
I don't care if you use bread-board, copper strips, matrix board or solder the components in the air as a "bird's nest." You only learn when the circuit gets turned on and WORKS!
In fact the rougher you build something, the more you will guarantee it will work when built on a printed circuit board.
However, high-frequency circuits (such as 100MHz FM Bugs) do not like open layouts and you have to keep the construction as tight as possible to get them to operate reliably.
In most other cases, the layout is not critical.
If you just follow these ideas, you will succeed.

A few of the basics are also provided in this eBook, the first is transistor outlines:

TRANSISTORS

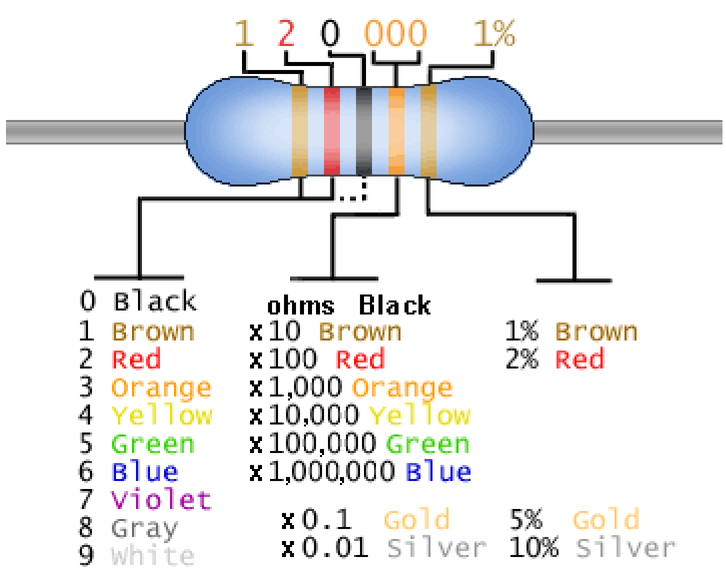
Most of the transistors used in our circuits are BC 547 and BC 557. These are classified as "universal" or "common" NPN and PNP types with a voltage rating of about 25v, 100mA collector current and a gain of about 100.
You can use almost any type of transistor to replace them and here is a list of the equivalents and pinouts:


NPN
c b e
BC 547
BC 337 / 8
PNP
c b e
BC 557
BC 327 / 8
NPN
TO-126
e
c
b
BD 139
BD 679 (darlington)
NPN
e b c
2N 3904
2N 2222
PNP
e b c
2N 3906
PNP
TO-126
e
c
b
BD 140
NPN
e c b
BC 639
PNP
e c b
BC 640
SOT23
b
c
e

CONTENTS

LED CRO LED Dice LED Zeppelin - a game of skill	555 74c14

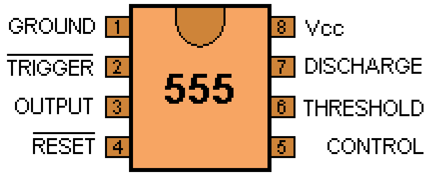
RESISTOR COLOUR CODE

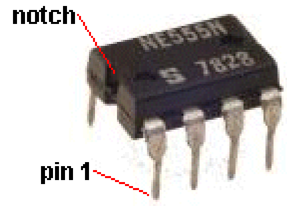


THE 555

The 555 is everywhere. It is possibly the most-frequency used chip and is easy to use.
But if you want to use it in a "one-shot" or similar circuit, you need to know how the chip will "sit."
For this you need to know about the UPPER THRESHOLD (pin 6) and LOWER THRESHOLD (pin 2):
The 555 is fully covered in a 3 page article on Talking Electronics website (see left index: 555 P1 P2 P3)

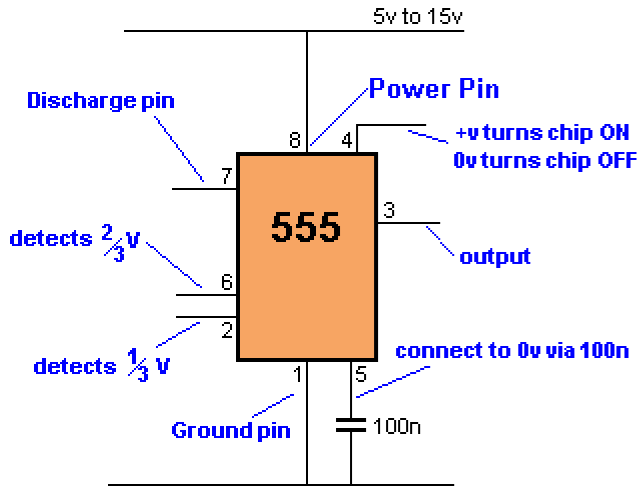
Here is the pin identification for each pin:



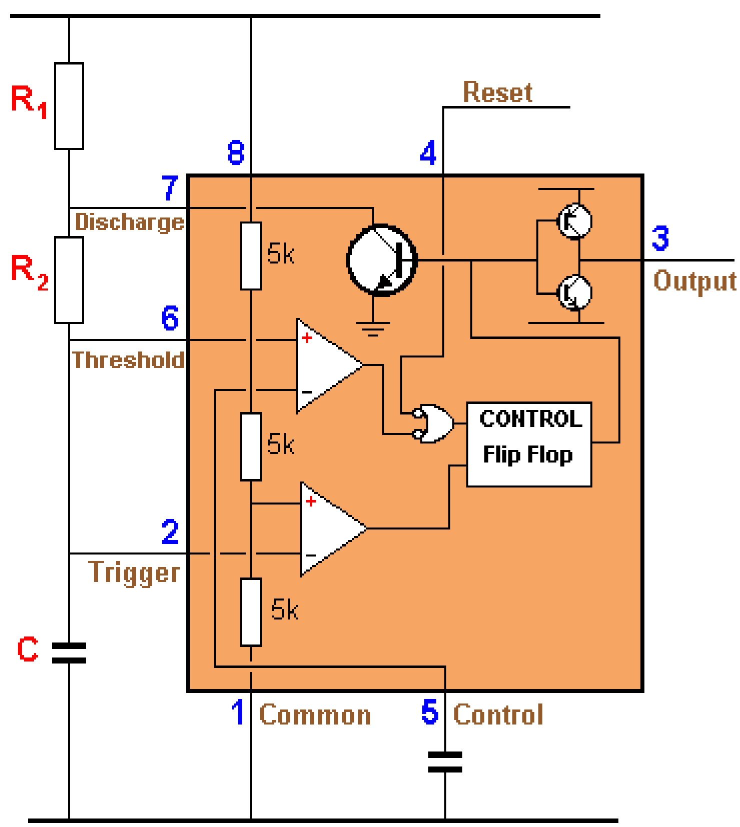


555 PINOUT

When drawing a circuit diagram, always draw the 555 as a building block with the pins in the following locations. This will help you instantly recognise the function of each pin:



The Function of each PIN



INSIDE THE 555 CHIP

Note: Pin 7 is "in phase" with output Pin 3 (both are low at the same time).
Pin 7 "shorts" to 0v via the transistor. It is pulled HIGH via R1.
Maximum supply voltage 16v - 18v
Current consumption approx 10mA
Output Current sink @5v = 5 - 50mA @15v = 50mA
Output Current source @5v = 100mA @15v = 200mA
Maximum operating frequency 300kHz - 500kHz

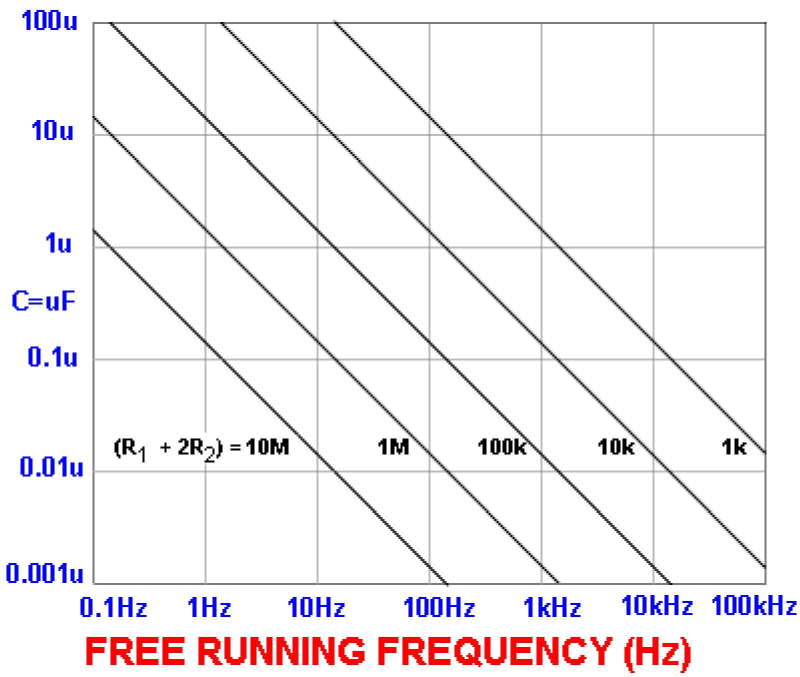
Faults with Chip:
Consumes about 10mA when sitting in circuit
Output voltage up to 2.5v **less than rail voltage**
Output is 0.5v to 1.5v above ground
Sources up to 200mA but sinks only 50mA

HOW TO USE THE 555

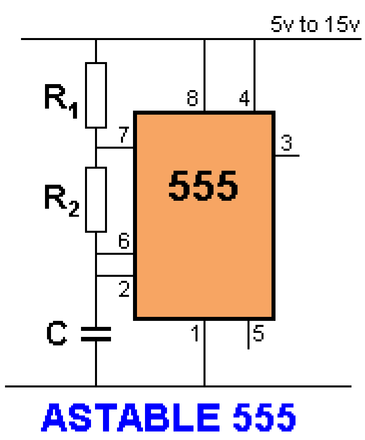
There are many ways to use the 55.
(a) Astable Multivibrator - constantly oscillates
(b) Monostable - changes state only once per trigger pulse - also called a ONE SHOT
(c) Voltage Controlled Oscillator

ASTABLE MULTIVIBRATOR

The output frequency of a 555 can be worked out from the following graph:



The graph applies to the following Astable circuit:



The capacitor C charges via R1 and R2 and when the voltage on the capacitor reaches 2/3 of the supply, pin 6 detects this and pin 7 connects to 0v. The capacitor discharges through R2 until its voltage is 1/3 of the supply and pin 2 detects this and turns off pin7 to repeat the cycle.
The top resistor is included to prevent pin 7 being damaged as it shorts to 0v when pin 6 detects 2/3 rail voltage.
Its resistance is small compared to R2 and does not come into the timing of the oscillator.

Using the graph:

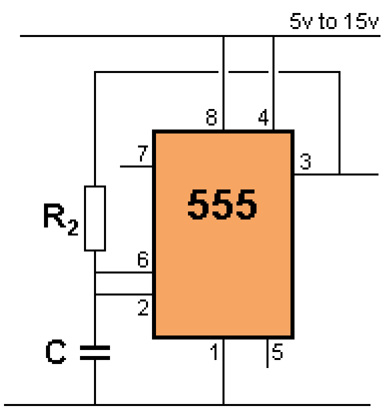
Suppose R1 = 1k, R2 = 10k and C = 0.1 (100n).
Using the formula on the graph, the total resistance = 1 + 10 + 10 = 21k
The scales on the graph are logarithmic so that 21k is approximately near the "1" on the 10k.
Draw a line parallel to the lines on the graph and where it crosses the 0.1u line, is the answer.
The result is approx 900Hz.

Suppose R1 = 10k, R2 = 100k and C = 1u
Using the formula on the graph, the total resistance = 10 + 100 + 100 = 210k
The scales on the graph are logarithmic so that 210k is approximately near the first "0" on the 100k. Draw a line parallel to the lines on the graph and where it crosses the 1u line, is the answer. The result is approx 9Hz.

The frequency of an astable circuit can also be worked out from the following formula:

$$\text{frequency} = \frac{1.4}{(R_1 + 2R_2) \times C}$$

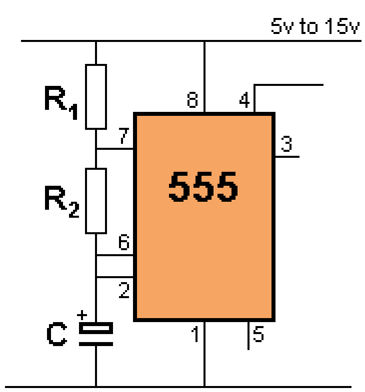
555 astable frequencies			
C	R_1 = 1k R_2 = 6k8	R_1 = 10k R_2 = 68k	R_1 = 100k R_2 = 680k
0.001µ	100kHz	10kHz	1kHz
0.01µ	10kHz	1kHz	100Hz
0.1µ	1kHz	100Hz	10Hz
1µ	100Hz	10Hz	1Hz
10µ	10Hz	1Hz	0.1Hz



SIMPLEST ASTABLE

The simplest Astable uses one resistor and one capacitor. Output pin 3 is used to charge and discharge the capacitor.

LOW FREQUENCY OSCILLATORS



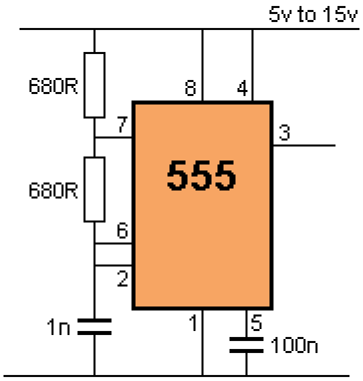
LOW FREQUENCY 555

If the capacitor is replaced with an electrolytic, the frequency of oscillation will reduce. When the frequency is less than 1Hz, the oscillator circuit is called a timer or "delay circuit." The 555 will produce delays as long as 30 minutes but with long delays, the timing is not accurate.

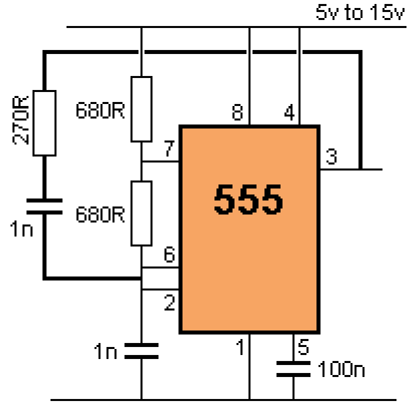
555 Delay Times:			
C	R_1 = 100k R_2 = 100k	R_1 = 470k R_2 = 470k	R_1 = 1M R_2 = 1M
10µ	2.2sec	10sec	22sec
100µ	22sec	100sec	220sec
470µ	100sec	500sec	1000sec

555 ASTABLE OSCILLATORS

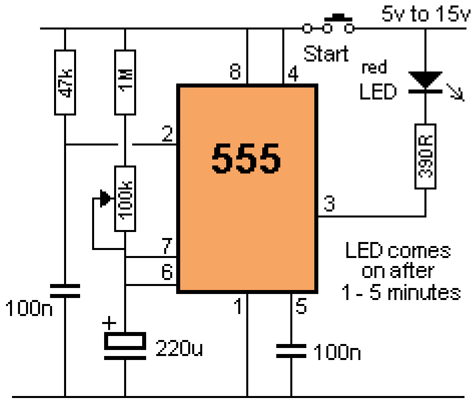
Here are circuits that operate from 300kHz to 30 minutes:
(300kHz is the absolute maximum as the 555 starts to malfunction with irregular bursts of pulses at this high frequency and 30 minutes is about the longest you can guarantee the cycle will repeat.)



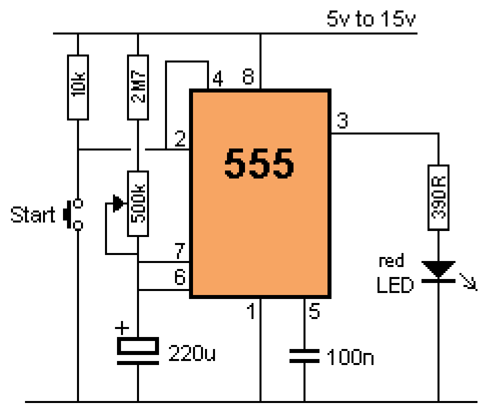
360kHz



360kHz - mods

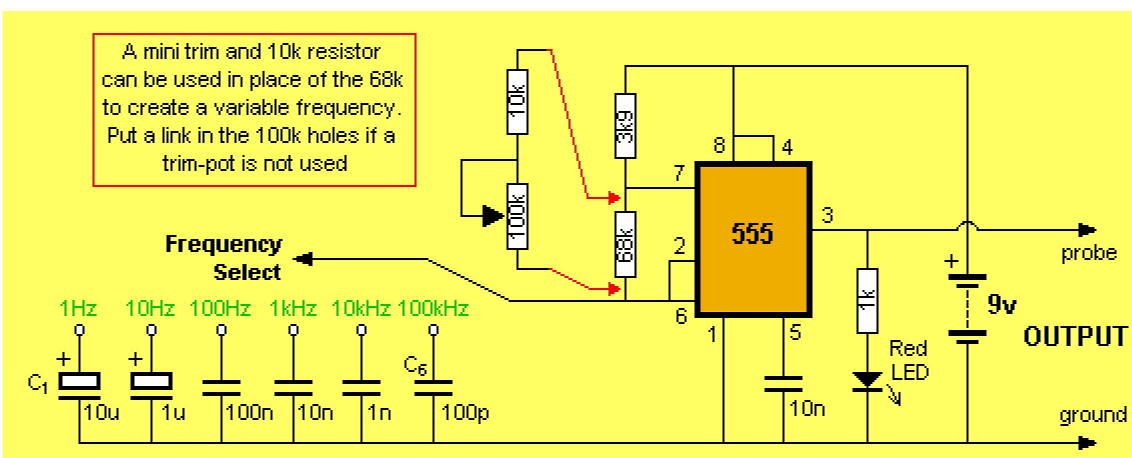


1 - 5 min TIMER



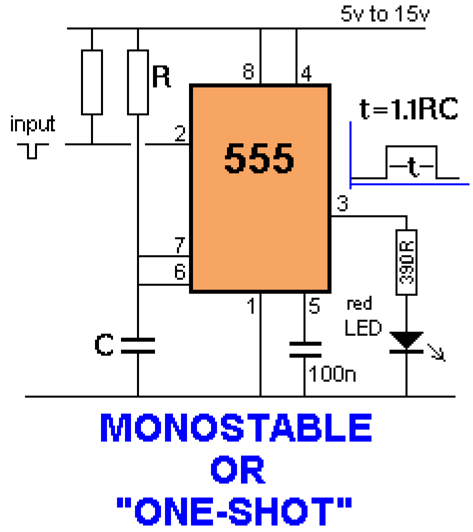
10 MINUTE TIMER

SQUARE WAVE OSCILLATOR

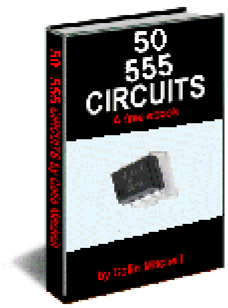


A square wave oscillator kit can be purchased from Talking Electronics for approx $10.00
See website: **Square Wave Oscillator**
It has adjustable (and settable) frequencies from 1Hz to 100kHz and is an ideal piece of Test Equipment.

555 Monostable or "one Shot"

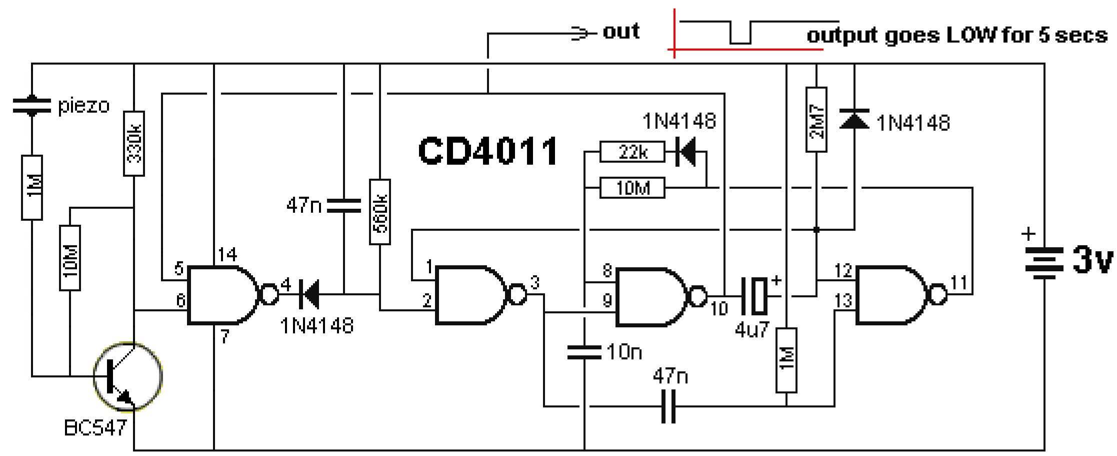


50 - 555 CIRCUITS



50 555 Circuits eBook can be accessed on the web or downloaded as a .doc or .pdf It has more than 50 very interesting 555 circuits and data on using a 555.

Table of Contents: (more has been added - see: 50 - 555 circuits)

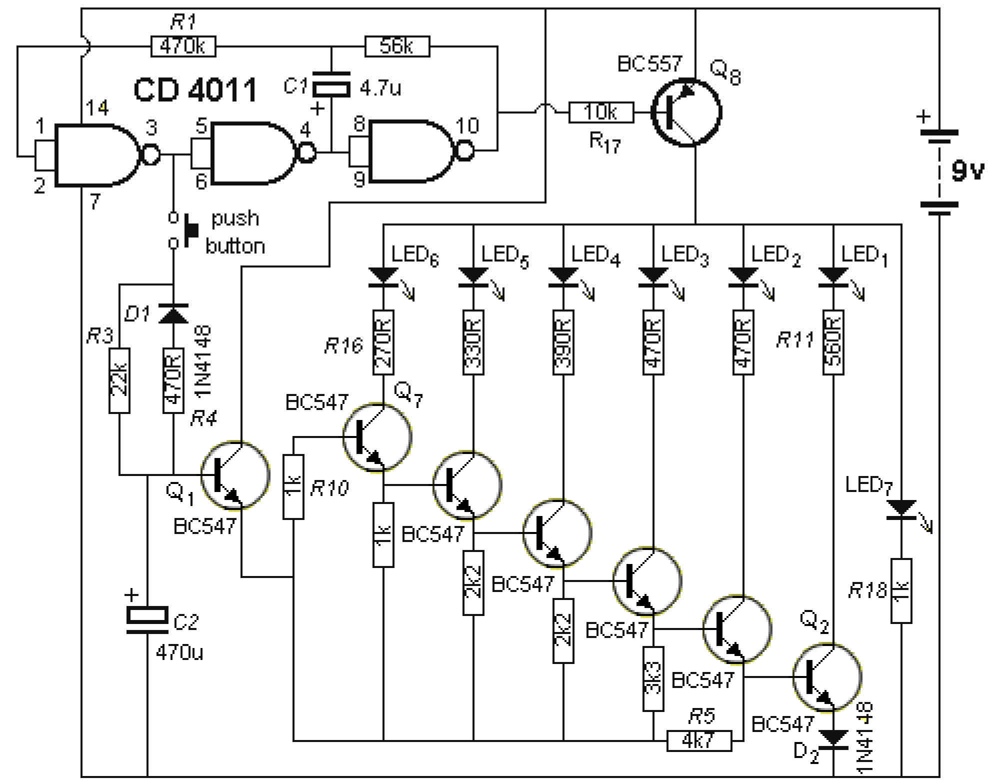


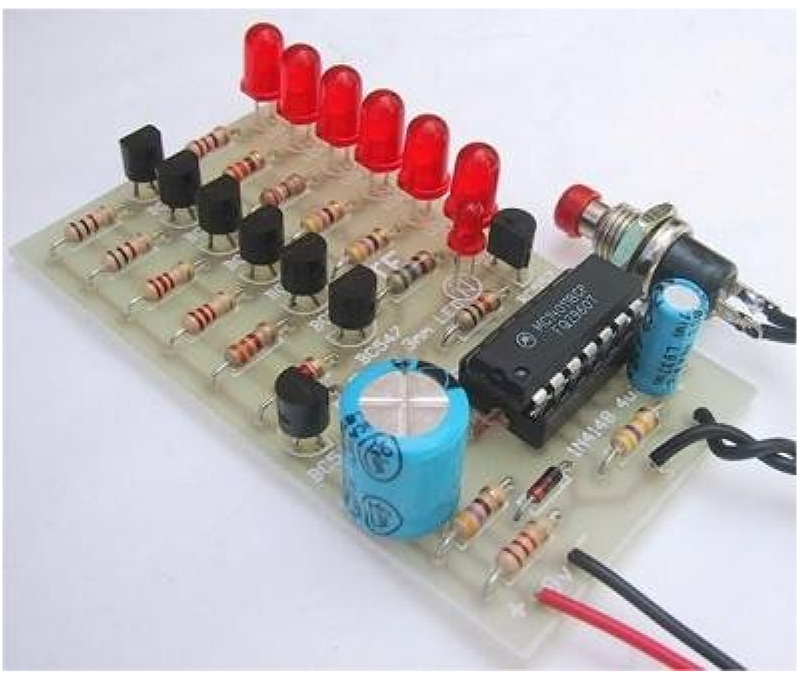
KNOCK KNOCK DOORBELL

This very clever circuit only produces an output when the piezo detects two taps. It can be used as a knock-knock doorbell. A PC board containing all components (soldered to the board) is available from talking electronics for $5.00 plus postage. Email HERE for details.
The circuit takes only a few microamp and when a tap is detected by the piezo, the waveform from the transistor produces a HIGH on pin 6 and the HIGH on pin 5 makes output pin 4 go low. This very quickly charges the 47n and it is discharged via the 560k to produce a brief pulse at pin 3.
The 47n is mainly to stop noise entering pin 2. Pin 1 is HIGH via the 2M7 and the LOW on pin 2 causes pin 3 to produce a HIGH pulse. The 47n is discharged via the internal diodes on pin 13 and when it goes LOW, pin 11 goes HIGH and charges the 10n via the 22k and diode.
This puts a HIGH on pin 8 for approx 0.7 seconds and when a second tap is detected, pin 9 sees a HIGH and pin 10 goes LOW. This puts a LOW on pin 12 and a HIGH on pin 8. The LOW on pin 12 goes to pin 1. A HIGH and LOW on the second NAND gate produces a HIGH on pin 3 and the third NAND gate has a HIGH on both inputs. This makes pin 10 LOW and the 4u7 starts to charge via the 2M7 resistor. After 5 seconds pin 12 sees a HIGH and pin 11 goes LOW. The 10n is discharged via the 10M and when pin 8 sees a LOW, pin 10 goes HIGH. The output sits HIGH and goes LOW for about 7 seconds.

LED ZEPPELIN

This circuit is a game of skill. See full article: LED Zeppelin. The kit is available from talking electronics for $15.50 plus postage. Email HERE for details.
The game consists of six LEDs and an indicator LED that flashes at a rate of about 2 cycles per second. A push button is the "Operations Control" and by carefully pushing the button in synchronisation with the flashing LED, the row of LEDs will gradually light up.
But the slightest mistake will immediately extinguish one, two or three LEDs. The aim of the game is to illuminate the 6 LEDs with the least number of pushes.
We have sold thousands of these kits. It's a great challenge.





LED Zeppelin Project - A Game of Skill

BFO METAL DETECTOR

The circuit shown must represent the limits of simplicity for a metal detector. It uses a single 4093 quad Schmitt NAND IC and a search coil -- and of course a switch and batteries. A lead from IC1d pin 11 needs to be attached to a MW radio aerial, or should be wrapped around the radio. If the radio has a BFO switch, switch this ON.

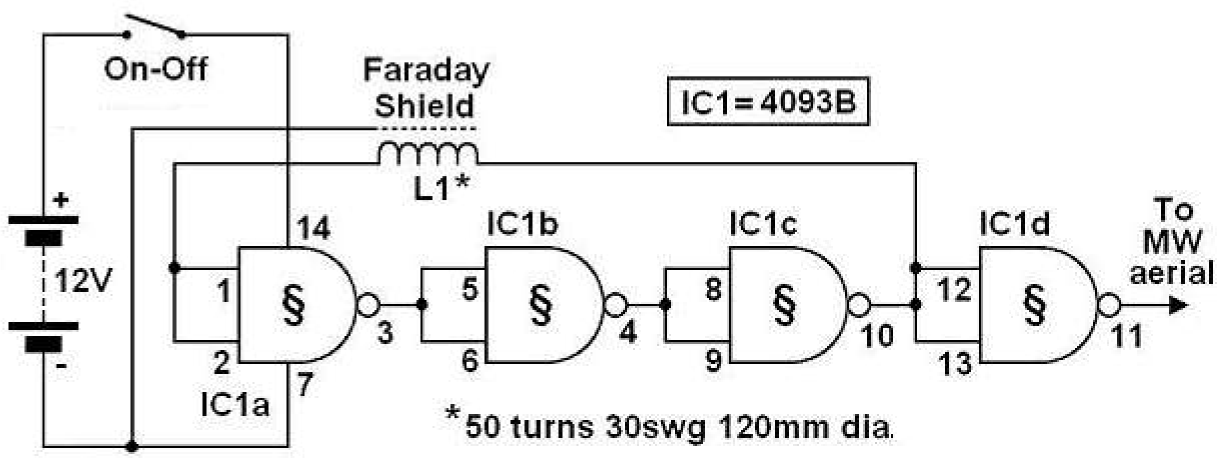
Since an inductor resists rapid changes in voltage (called reactance), any change in the logic level at IC1c pin 10 is delayed during transfer back to input pins 1 and 2. This is further delayed through propagation delays within the 4093 IC. This sets up a rapid oscillation (about 2 MHz), which is picked up by a MW radio. Any change to the inductance of L1 (through the presence of metal) brings about a change to the oscillator frequency. Although 2 MHz is out of range of the Medium Waves, a MW radio will clearly pick up harmonics of this frequency.

The winding of the coil is by no means critical, and a great deal of latitude is permissible. The prototype used 50 turns of 22 awg/30 swg (0.315 mm) enamelled copper wire, wound on a 4.7"/120 mm former. This was then wrapped in insulation tape. The coil then requires a Faraday shield, which is connected to

0V. A Faraday shield is a wrapping of tin foil around the coil, leaving a small gap so that the foil does not complete the entire circumference of the coil. The Faraday shield is again wrapped in insulation tape. A connection may be made to the Faraday shield by wrapping a bare piece of stiff wire around it before adding the tape. Ideally, the search coil will be wired to the circuit by means of twin-core or figure-8 microphone cable, with the screen being wired to the Faraday shield.

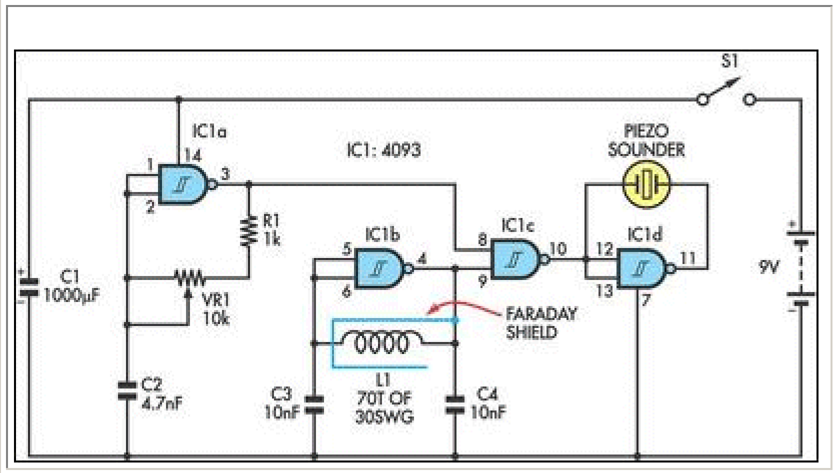
The metal detector is set up by tuning the MW radio to pick up a whistle (a harmonic of 2 MHz). Note that not every such harmonic works best, and the most suitable one needs to be found. The presence of metal will then clearly change the tone of the whistle. The metal detector has excellent stability, and it should detect a large coin at 80 to 90 mm, which for a BFO detector is relatively good. It will also discriminate between ferrous and non-ferrous metals through a rise or fall in tone.

The author may be contacted at scarboro@iafrica.com



SIMPLE BFO METAL LOCATOR

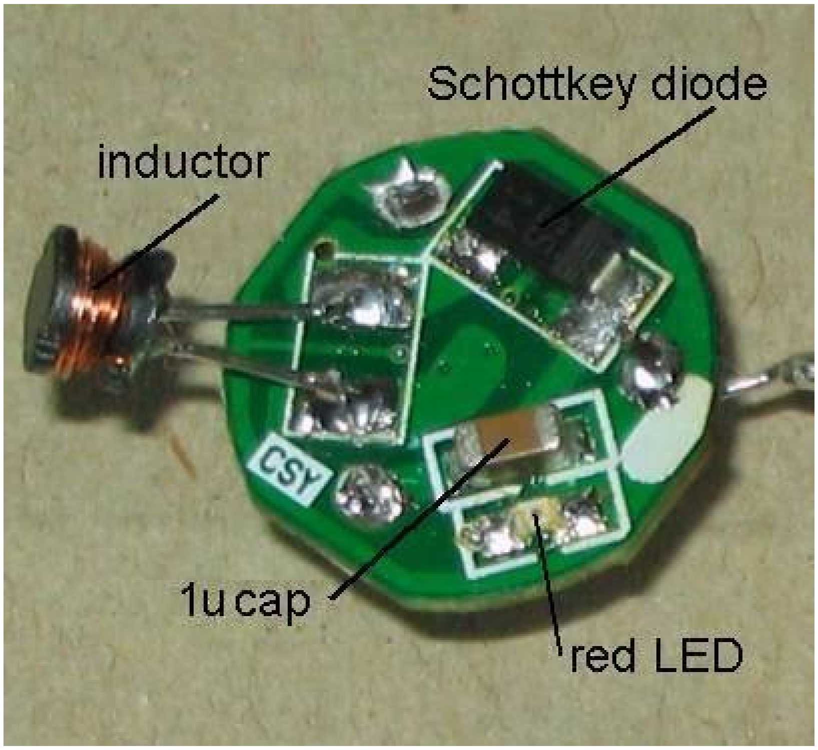
This circuit uses a single coil and nine components to make a particularly sensitive low-cost metal locator. It works on the principle of a beat frequency oscillator (BFO).
The circuit incorporates two oscillators, both operating at about 40kHz. The first, IC1a, is a standard CMOS oscillator with its frequency adjustable via VR1.
The frequency of the second, IC1b, is highly dependent on the inductance of coil L1, so that its frequency shifts in the presence of metal. L1 is 70 turns of 0.315mm enamelled copper wire wound on a 120mm diameter former. The Faraday shield is made of aluminum foil, which is wound around all but about 10mm of the coil and connected to pin 4 of IC1b.
The two oscillator signals are mixed through IC1c, to create a beat note. IC1d and IC1c drive the piezo sounder in push-pull fashion, thereby boosting the output.
Unlike many other metal locators of its kind, this locator is particularly easy to tune. Around the midpoint setting of VR1, there will be a loud beat frequency with a null point in the middle. The locator needs to be tuned to a low frequency beat note to one or the other side of this null point.
Depending on which side is chosen, it will be sensitive to either ferrous or non-ferrous metals. Besides detecting objects under the ground, the circuit could serve well as a pipe locator.

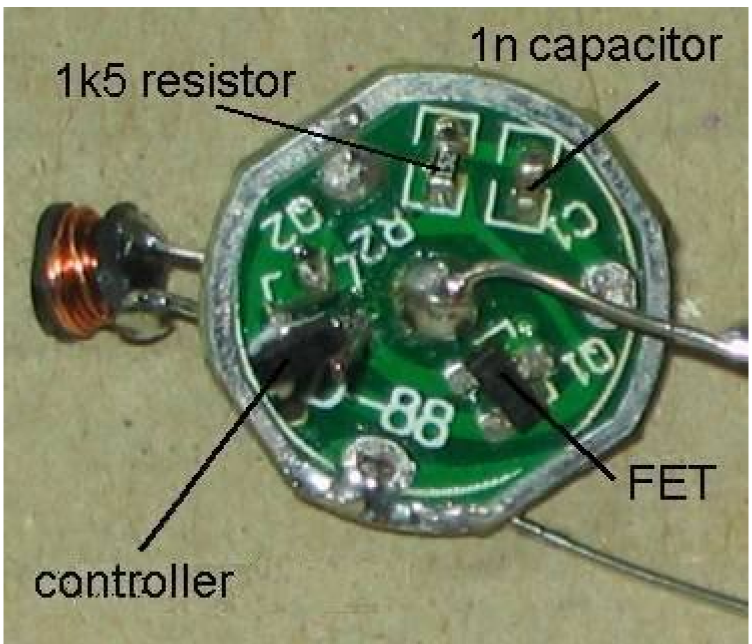


1.5v to 5v PHONE CHARGER

Look at the photos. The circuit is simple. It looks like two surface-mount transistors, an inductor, diode, capacitor, resistor and LED.
But you will be mistaken.
One of the "transistors" is a controller and the other is a FET.
The controller is powered from the output (5v) of the circuit and when it detects no-load, it shuts down and requires a very small current.
When the 1v5 batter is connected, the controller starts up at less than 1v5 due to the Schottkey diode and charges the 1u capacitor by driving the FET and using the flyback effect of the inductor to produce a high voltage. When the output voltage is 5v, the controller turns off and the only load on the 1u is the controller. When the voltage drops across this capacitor, the controller turns on in bursts to keep the 1u charged to exactly 5v. The charger was purchased for $3.00 so it is cheaper to buy one and use it in your own project. It also comes with 4 adapter leads!

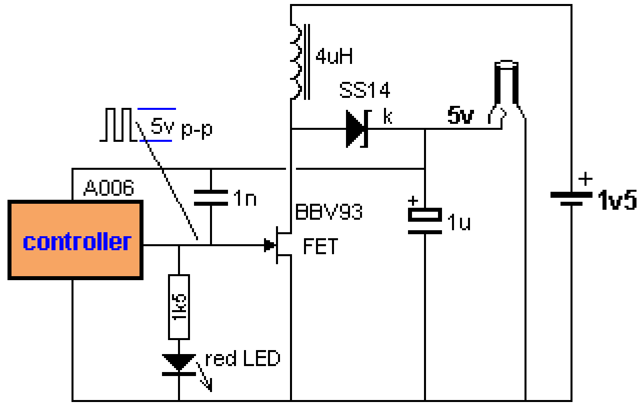
The AA case and 4 adapter leads - cost: $3.00!!





The controller has been placed on extension wires to test its operation.

The LED and 1u capacitor can be clearly seen in this photo.

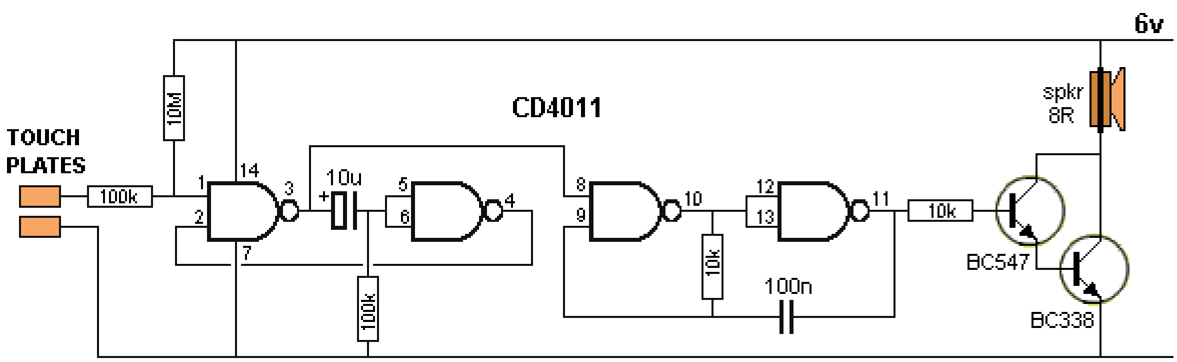


PHONE CHARGER

Sometimes it is better to use something that is already available, rather than trying to re-invent the wheel. This is certainly the case with this project. You could not buy the components for the cost of the complete phone charger and extension leads.
The circuit will deliver 70mA at 5v and if a higher current is drawn, the voltage drops slightly.
These chargers were originally priced at $30.00 !!

10 SECOND ALARM

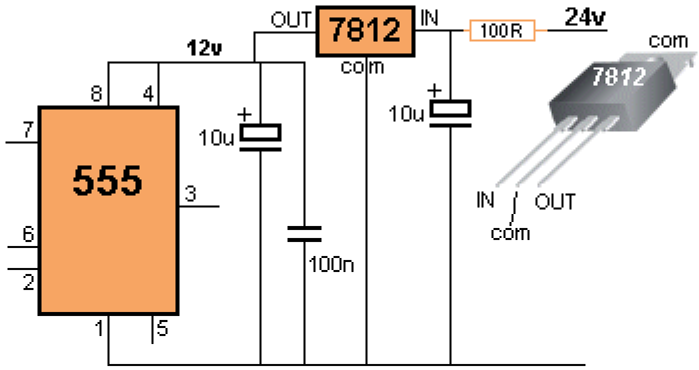
This circuit is activated for 10 seconds via the first two gates. They form a LATCH to keep the oscillator (made up of the next two gates) in operation, to drive the speaker.
The circuit consumes a few microamps in quiescent mode and the TOUCH PLATES can be any type of foil on a door knob or item that is required to be protected. The 10u sits in an uncharged condition and when the plates are touched, the voltage on pin 1 drops below 50% rail and makes pin 3 HIGH. This pulls pins 5 and 6 HIGH and makes pin 4 LOW. This keeps pin 3 HIGH, no matter if a HIGH or LOW is on pin1. This turns on the oscillator and the 10u starts to charge via the 100k resistor. After about 10 seconds, the voltage on pins 5 and 6 drops to below 50% rail voltage and pin 4 goes HIGH. If the TOUCH PLATES are not touched, pin 3 will go LOW and the oscillator will stop.



10 SECOND ALARM

USING A VOLTAGE REGULATOR

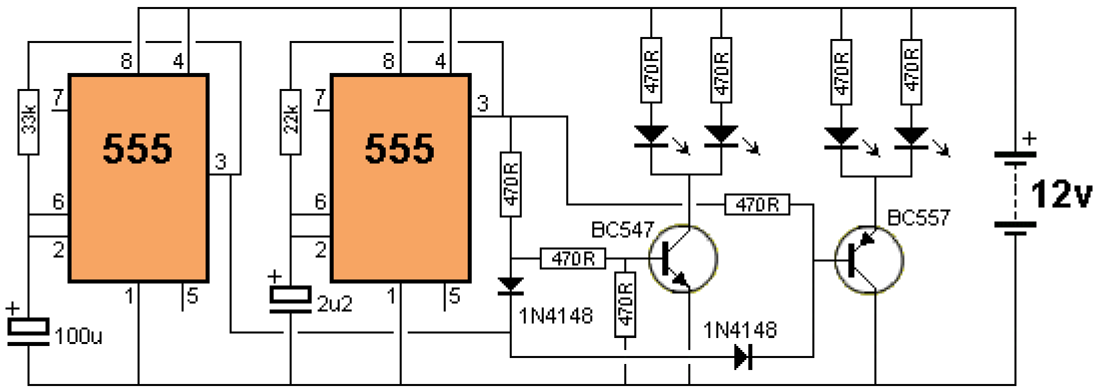
This circuit shows how to use a voltage regulator to convert a 24v supply to 12v for a 555 chip. Note: the pins on the regulator (commonly called a 3-terminal regulator) are: IN, COMMON, OUT and these must match-up with: In, Common, Out on the circuit diagram.
If the current requirement is less than 500mA, a 100R "safety resistor" can be placed on the 24v rail to prevent spikes damaging the regulator.



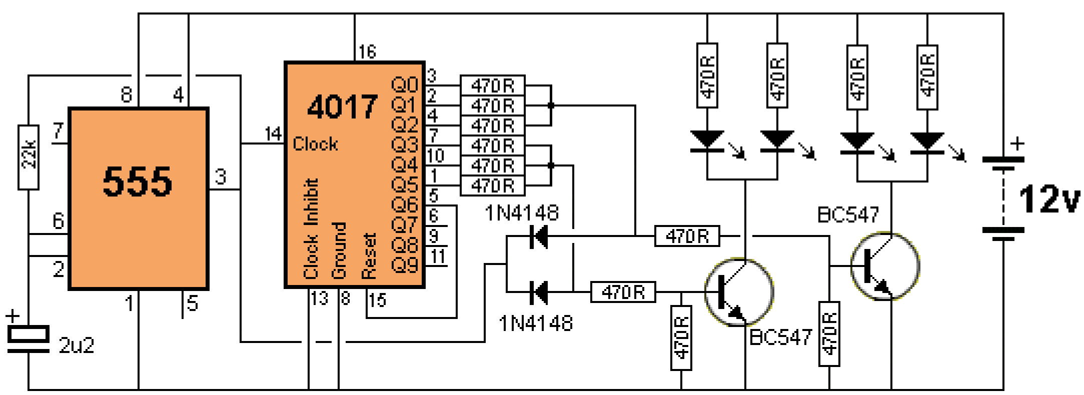
using a voltage regulator

POLICE LIGHTS

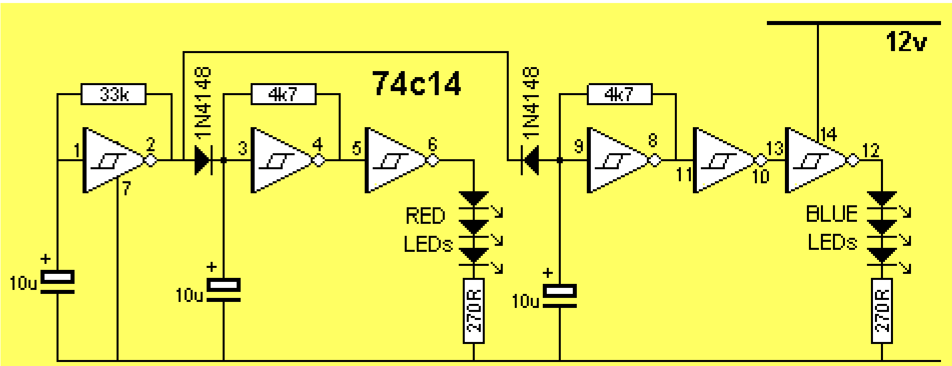
These three circuits flash the left LEDs 3 times then the right LEDs 3 times, then repeats. The only difference is the choice of chips.



POLICE LIGHTS



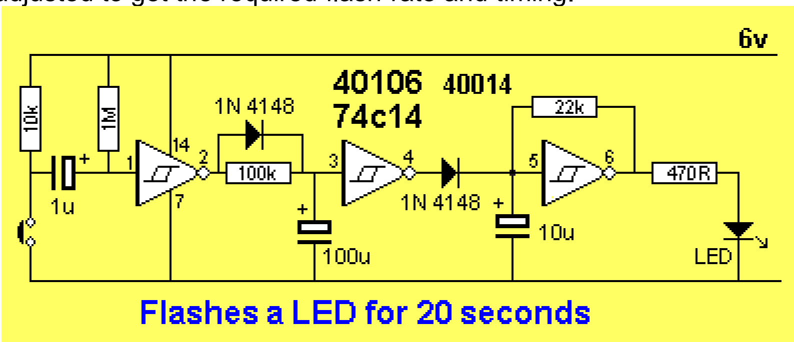
POLICE LIGHTS - 2



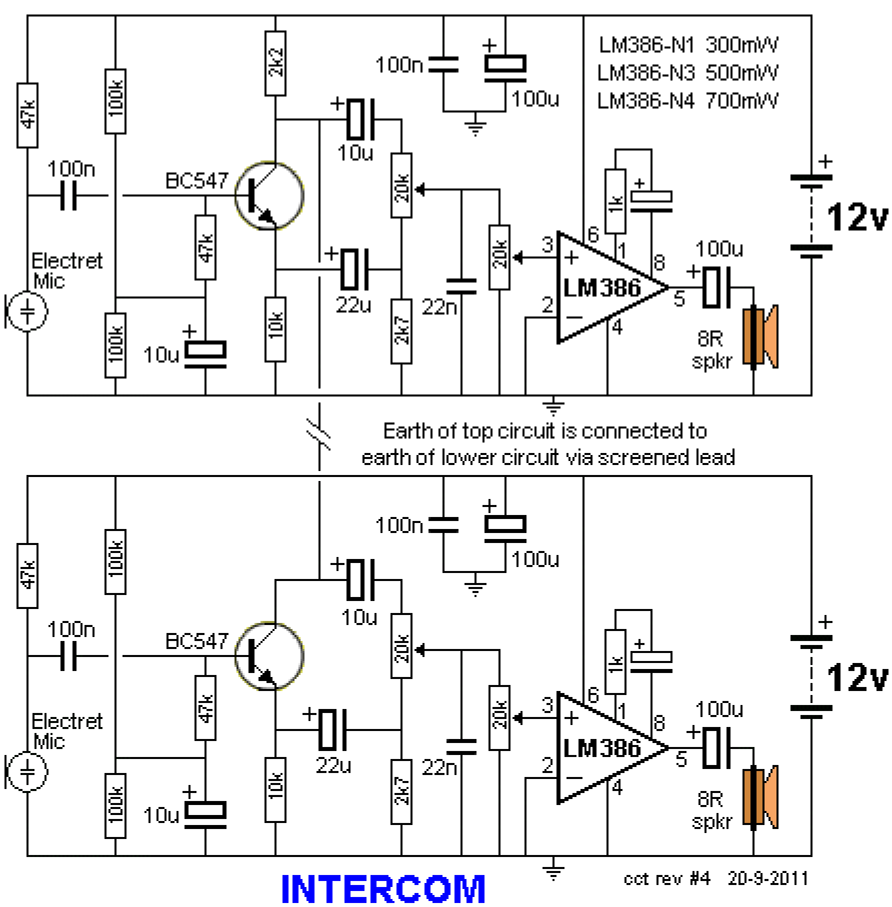
POLICE LIGHTS-3

FLASH LEDS FOR 20 SECONDS

This circuit comes from a request from a reader. It flashes a LED for 20 seconds after a switch is pressed. In other words, for 20 seconds as soon as the switch is pressed. The values will need to be adjusted to get the required flash-rate and timing.



INTERCOM



This circuit uses a single transistor and LM386 amplifier IC to produce an intercom that allows hands-free operation.

As both microphones and loudspeakers are always connected, the circuit is designed to avoid feedback - known as the "Larsen effect".

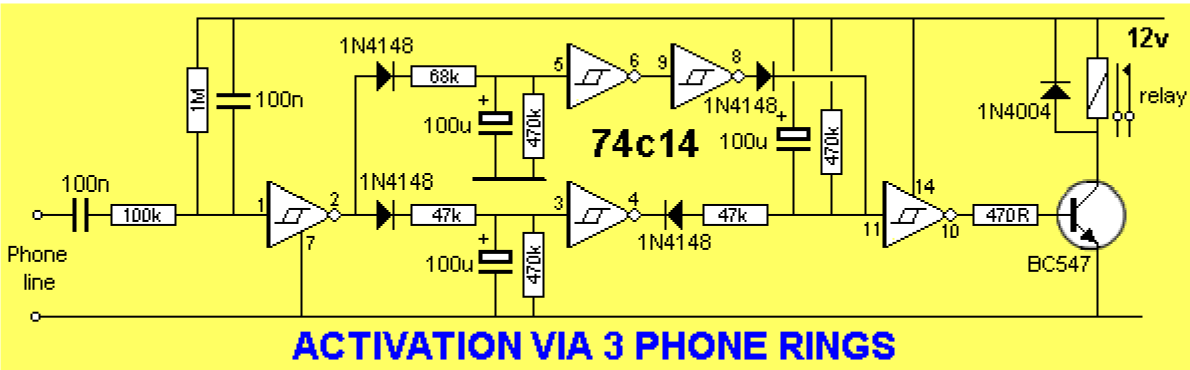
The microphone amplifier transistor is 180° phase-shifted and one of the audio outputs is taken at the collector and its in-phase output taken at the emitter. These are mixed by the 10u, 22u, 20k pot and 2k7 so that the two signals almost cancel out. In this way, the loudspeaker will reproduce a very faint copy of the signals picked-up by the microphone.

At the same time, as both collectors of the two intercom units are tied together, the 180° phase-shifted signal will pass to the audio amplifier of the second unit without attenuation, so it will be loudly reproduced by its loudspeaker.

The same operation will occur when speaking into the microphone of the second unit. When the 20k pot is set correctly, almost no output will be heard from the loudspeaker but a loud and clear reproduction will be heard at the output of the other unit. The second 20k pot adjusts the volume.

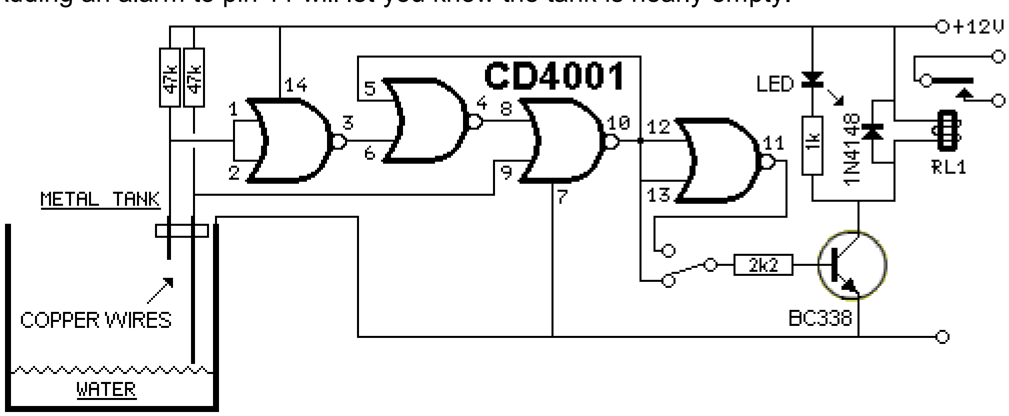
ACTIVATE VIA 3 PHONE RINGS

This circuit connects to a phone line. When the phone rings for 3 or 4 rings, the relay is activated for about 1 minute. But if the phone rings for 6 or more rings, the circuit is not activated.
The circuit takes less than 100uA when in quiescent state and when the phone rings, the ring voltage is passed to pin 1 via the 100k and 100n capacitor. This causes pin 2 to go HIGH and charge two 100u electrolytics. The lower 100u charges in 7 seconds and the upper charges in 12 seconds. If the phone rings for only 3 rings, pin 4 goes LOW and charges the third 100u via a 47k resistor. After a further 7 seconds, pin 10 goes HIGH. If the phone stops ringing after 3 rings, the lower 100u starts to discharge via the 470k and after about 40 seconds pin 4 goes HIGH. The third 100u now starts to discharge via the 470k across it and the relay turns off.
If the phone rings for more than 5 rings, the top 100u will charge and pin 6 will go LOW and cause pin 8 to go HIGH and prevent pin 11 going LOW via the gating diode.



WATER LEVEL PUMP CONTROLLER

This circuit provides automatic level control of a water tank.
The shorter steel rod is the "water high" sensor and the longer is the "water low" sensor. When the water level is below both sensors, pin 10 is low. If the water comes in contact with the longer sensor the output remains low until the shorter sensor is reached. At this point pin11 goes high and the transistor conducts. The relay is energized and the pump starts operating. When the water level drops the shorter sensor will be no longer in contact with the water, but the output of the IC will keep the transistor tuned ON until the water falls below the level of the longer rod. When the water level falls below the longer sensor, the output of the IC goes low and the pump will stop.
The switch provides reverse operation. Switching to connect the transistor to pin 11 of the IC will cause the pump will operate when the tank is nearly empty and will stop when the tank is full. In this case, the pump will be used to fill the tank and not to empty it.
Note: The two steel rods must be supported by a small insulated (wooden or plastic) board. The circuit can be used also with non-metal tanks, provided a third steel rod having about the same height as the tank is connected to the negative.
Adding an alarm to pin 11 will let you know the tank is nearly empty.

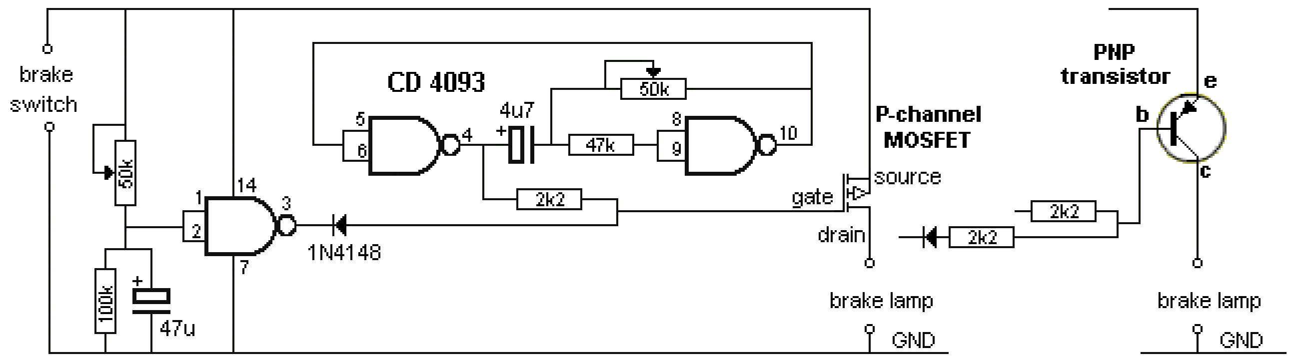


BRAKE LIGHTS

This circuit makes the brake lights flash a number of times then stay ON. The circuit shows how a MOSFET works. The MOSFET is turned on with a voltage between the gate and source. This occurs in the circuit when the gate is LOW. The P-channel MOSFET can be replaced by a PNP transistor with the addition of a 2k2 between the diode and base, to prevent the transistor being damaged when output pin 3 goes LOW. Ideally the PNP transistor should be replaced with a Darlington transistor.
This circuit originally designed by:
Ken Moffett
Scientific Instrumentation

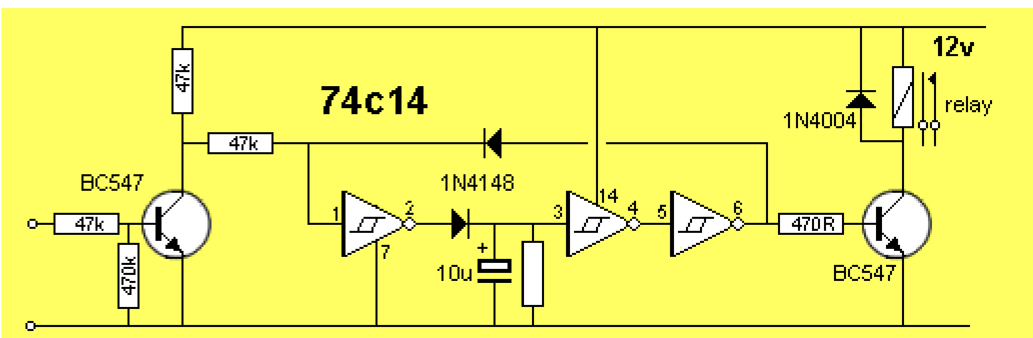
Macalester College
1600 Grand Avenue
St Paul MN 55105
moffett@macalester.edu

See the full article:
http://www.sentex.net/~mec1995/circ/motflash.html .pdf of article

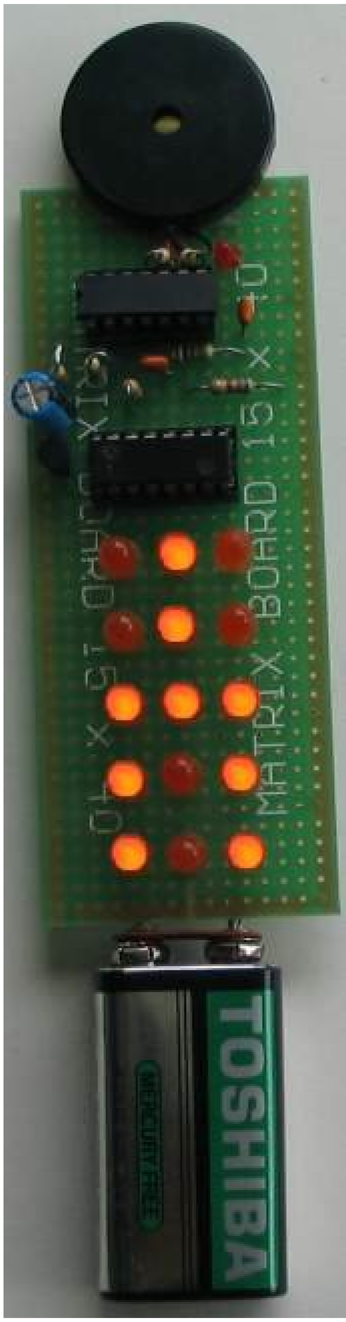


ACTIVE FOR 1 SECOND

This circuit is active for 1 second after it detects a signal on the base of the input transistor. The length of activation depends on the value of the resistor across the 10u electrolytic.
When pin 1 goes LOW, pin 2 goes HIGH and charges the 10u. Pin 3 goes HIGH, pin 4 goes LOW and pin 6 goes HIGH to turn on the transistor and activate the relay.
At the same time a HIGH is passed to pin 1 to keep it HIGH.
Pin 2 will be kept LOW and the 10u will discharge via the resistor across it and eventually pin 3 will go LOW and the relay will turn off. If a signal is still present on the base of the input transistor, the relay will remain energised as the circuit will charge the 10u again.



THE DOMINO EFFECT



Here's a project with an interesting name. The original design was bought over 40 years ago, before the introduction of the electret microphone. They used a crystal earpiece.

We have substituted it with a piezo diaphragm and used a quad op-amp to produce two building blocks. The first is a high-gain amplifier to take the few millivolts output of the piezo and amplify it sufficiently to drive the input of a counter chip. This requires a waveform of at least 6v for a 9v supply and we need a gain of about 600.

The other building block is simply a buffer that takes the high-amplitude waveform and delivers the negative excursions to a reservoir capacitor (100u electrolytic). The charge on this capacitor turns on a BC557 transistor and this effectively takes the power pin of the counter-chip to the positive rail via the collector lead.

The chip has internal current limiting and some of the outputs are taken to sets of three LEDs.

The chip is actually a counter or divider and the frequency picked up by the piezo is divided by 128 and delivered to one output and divided by over 8,000 by the highest-division output to three more LEDs The other lines have lower divisions.

This creates a very impressive effect as the LEDs are connected to produce a balanced display that changes according to the beat of the music.

The voltage on the three amplifiers is determined by the 3M3 and 1M voltage-divider on the first op-amp. It produces about 2v. This makes the output go HIGH and it takes pin 2 with it until this pin see a few millivolts above pin3. At this point the output stops rising.

Any waveform (voltage) produced by the piezo that is lower than the voltage on pin 3 will make the output go HIGH and this is how we get a large waveform.

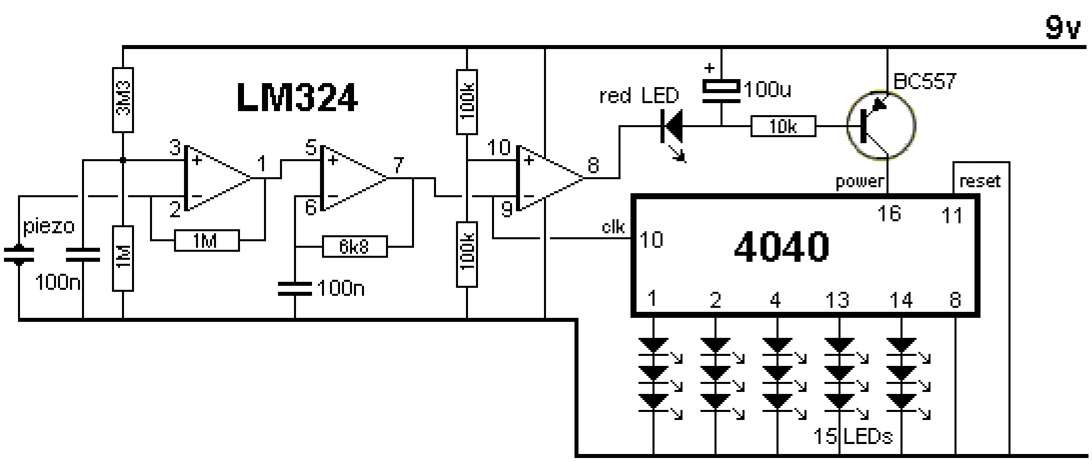
This signal is passed to the second op-amp and because the voltage on pin 6 is delayed slightly by the 100n capacitor, is also produces a gain.

When no signal is picked up by the piezo, pin 7 is approx 2v and pin 10 is about 4.5v. Because pin 9 is lower than pin 10, the output pin 8 is about 7.7v (1.3v below the supply rail) as this is as high as the output will go - it does not go full rail-to-rail.

The LED connected to the output removes 1.7v, plus 0.6v between base and emitter and this means the transistor is not turned on.

Any colour LEDs can be used and a mixture will give a different effect.

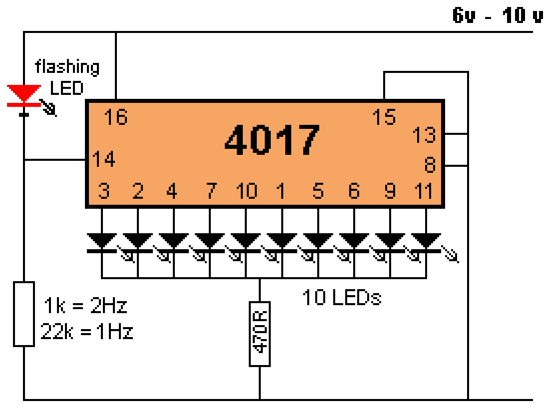
Click the link above for more details on the project, including photos and construction notes.



10 LED CHASER

Here's an interesting circuit that creates a clock pulse for a 4017 from a flashing LED. The flashing LED takes almost no current between flashes and thus the clock line is low via the 1k to 22k resistor.

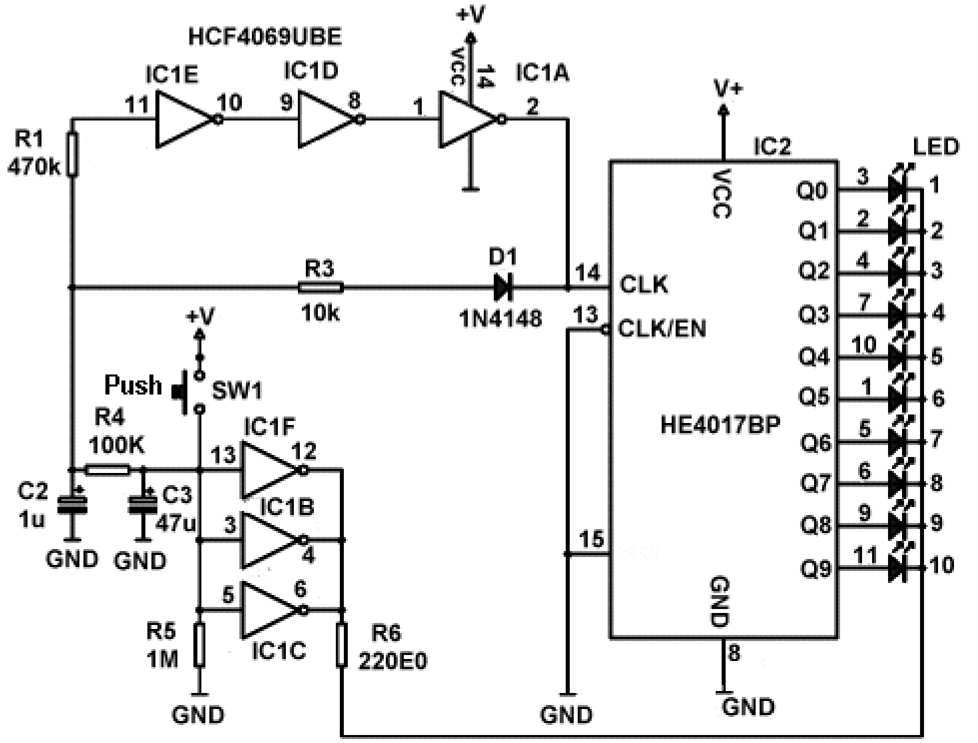
When the LED flashes, the voltage on the clock line is about 2v -3v below the rail voltage (depending on the value of the resistor) and this is sufficient for the chip to see a HIGH.



(circuit designed on 9-10-2010)

WHEEL OF FORTUNE

Here's a circuit from Vellemann.
The slow-down circuit consists of the top three gates, R3, D1, C2, R4 and C3.
Sw1 is pressed for a brief period.
This charges the 47u and the 1u is charged via the 100k.
The voltage on the 1u rises until it puts a HIGH on input pin 11.
This puts a LOW on pin 2 and the voltage on the 1u drops until the voltage on pin 11 is a LOW.
The voltage fluctuates at about half rail voltage as it puts a HIGH and LOW on Pin 11. It is charged by the 100k and discharged by the 10 and diode.
The HIGH on pin 2 allows the 1u to charge via the 100k and this gradually reduces the voltage on the 47u.
As the voltage on the 47u falls, the time taken to charge the 1u increases and creates the slow-down effect. Eventually the voltage on the 1u is not enough to put a HIGH on Pin 11 and the circuit freezes.

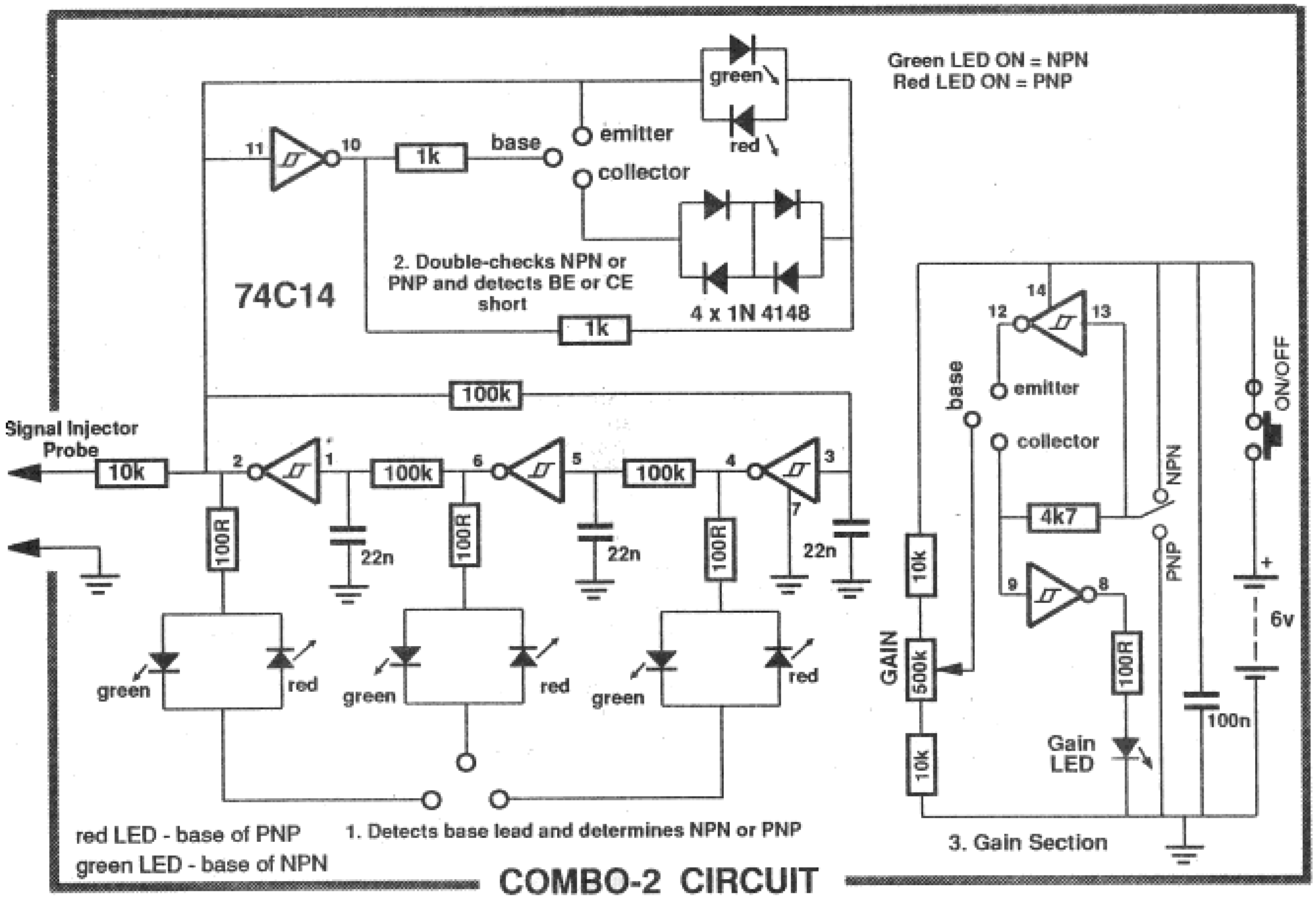


Wheel of Fortune

TRANSISTOR TESTER COMBO-2

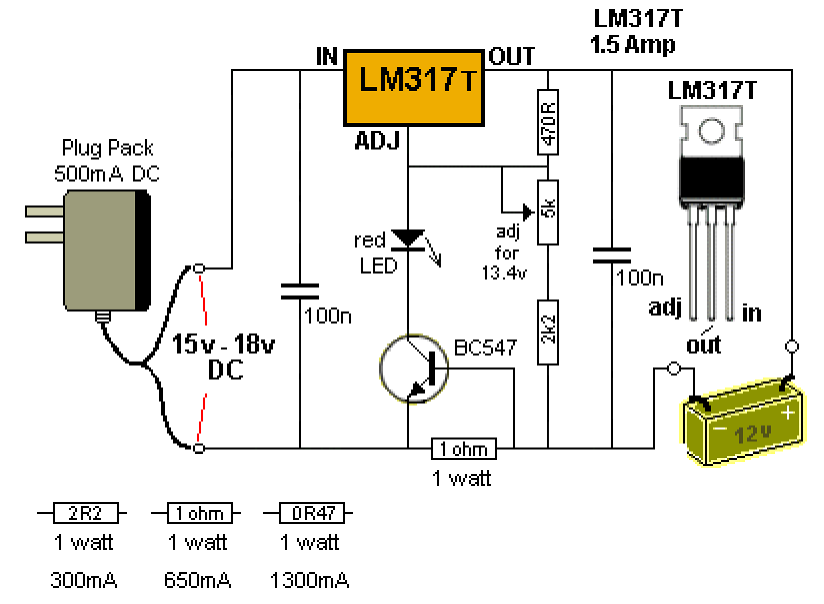
The circuit uses a single IC to perform 3 tests:

Test 1: Place the transistor in any orientation into the three terminals of circuit 1 (below, left) and a red LED will detect the base of a PNP transistor an a green LED will indicate the base of an NPN transistor.
Test 2: You now now the base lead and the type of transistor. Place the transistor in Test 2 circuit (top circuit) and when you have fitted the collector and emitter leads correctly (maybe have to swap leads), the red or green LED will come on to prove you have fitted the transistor correctly.
Test 3: The transistor can now be fitted in the GAIN SECTION. Select PNP or NPN and turn the pot until the LED illuminates. The value of gain is marked on the PCB that comes with the kit. The kit has ezy clips that clip onto the leads of the transistor to make it easy to use the project.
The project also has a probe at one end of the board that produces a square wave - suitable for all sorts of audio testing and some digital testing.
Project cost: $22.00 from Talking Electronics.



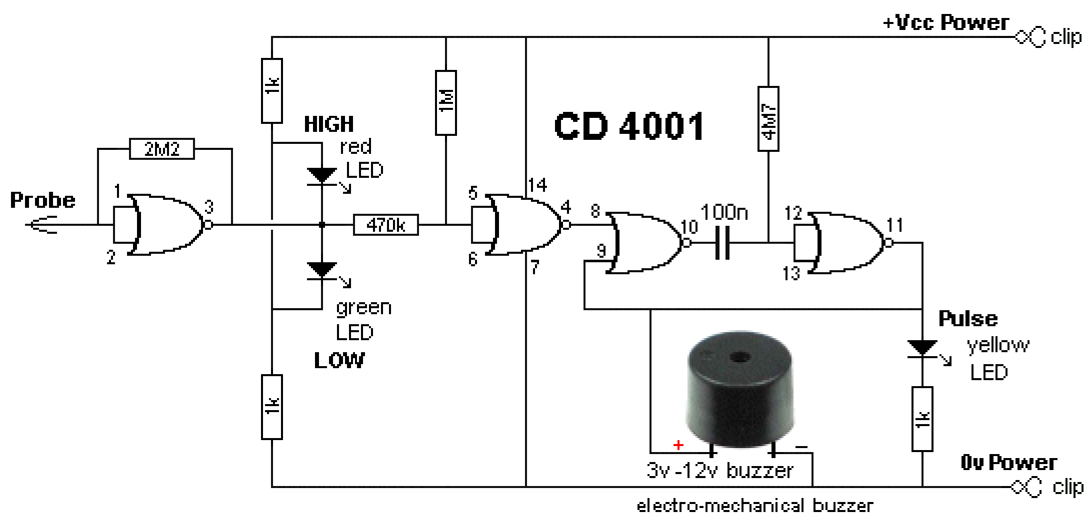
GELL CELL BATTERY CHARGER

This circuit will charge gell cell batteries at 300mA or 650mA or 1.3A, depending on the CURRENT SENSING resistor in the 0v rail. Adjust the 5k pot for 13.4v out and when the battery voltage reaches this level, the current will drop to a few milliamps. The plug pack will need to be upgraded for the 650mA or 1.3A charge-current. The red LED indicates charging and as the battery voltage rises, the current-flow decreases. The maximum is shown below and when it drops about 5%, the LED turns off and the current gradually drops to almost zero.

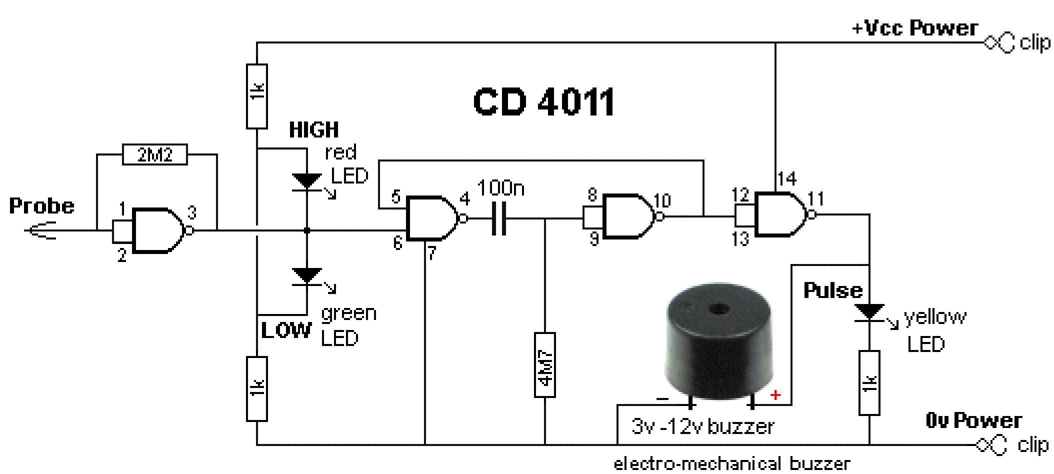


SIMPLE LOGIC PROBE

Here is a simple Logic Probe using a single chip. The circuits have been designed for the **CD4001** CMOS quad NOR gate and **CD4011** CMOS NAND gate. The output has an active buzzer that produces a beep when the pulse LED illuminates. The buzzer is not a piezo-diaphragm but an active buzzer containing components. It is called an electro-mechanical buzzer as it has two coils. The main coil pulls the diaphragm to the core via a transistor and the feedback coil drives the base. When the transistor is fully saturated, the feedback winding does not see any induced voltage (and current) and the transistor turns OFF. The rapid action of this oscillator produces an annoying squeal.

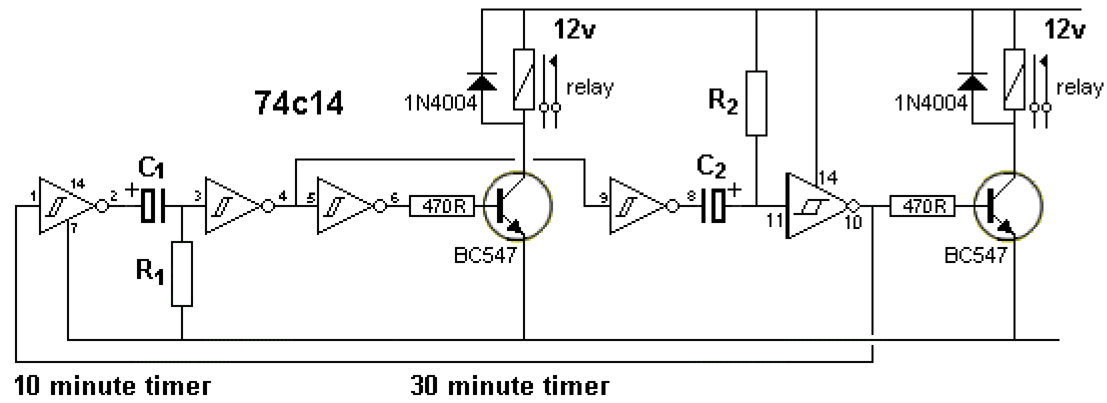


LOGIC PROBE USING CD 4001



LOGIC PROBE USING CD 4011

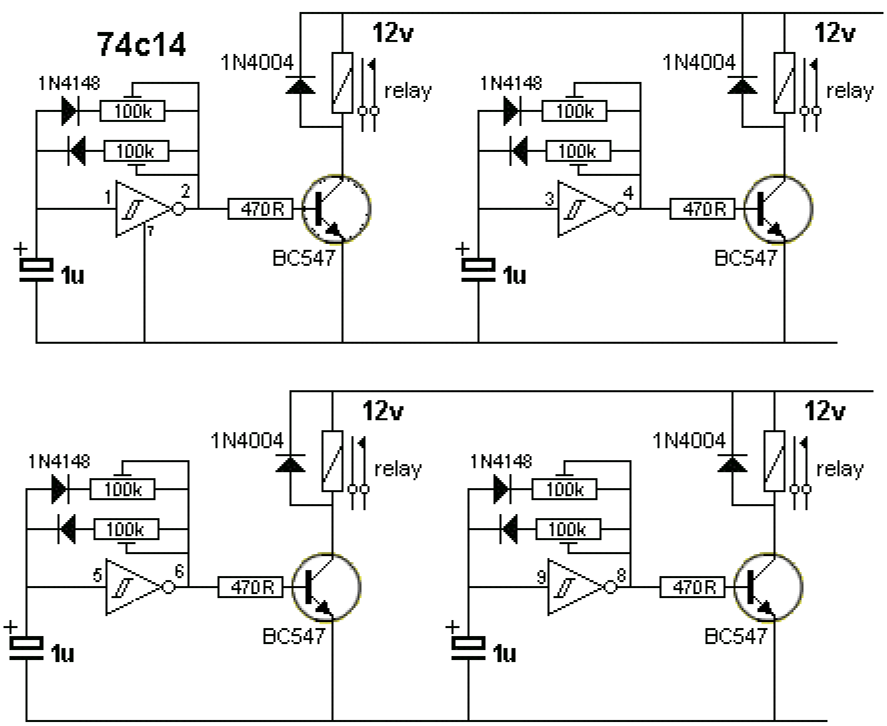
10 MINUTE AND 30 MINUTE TIMER

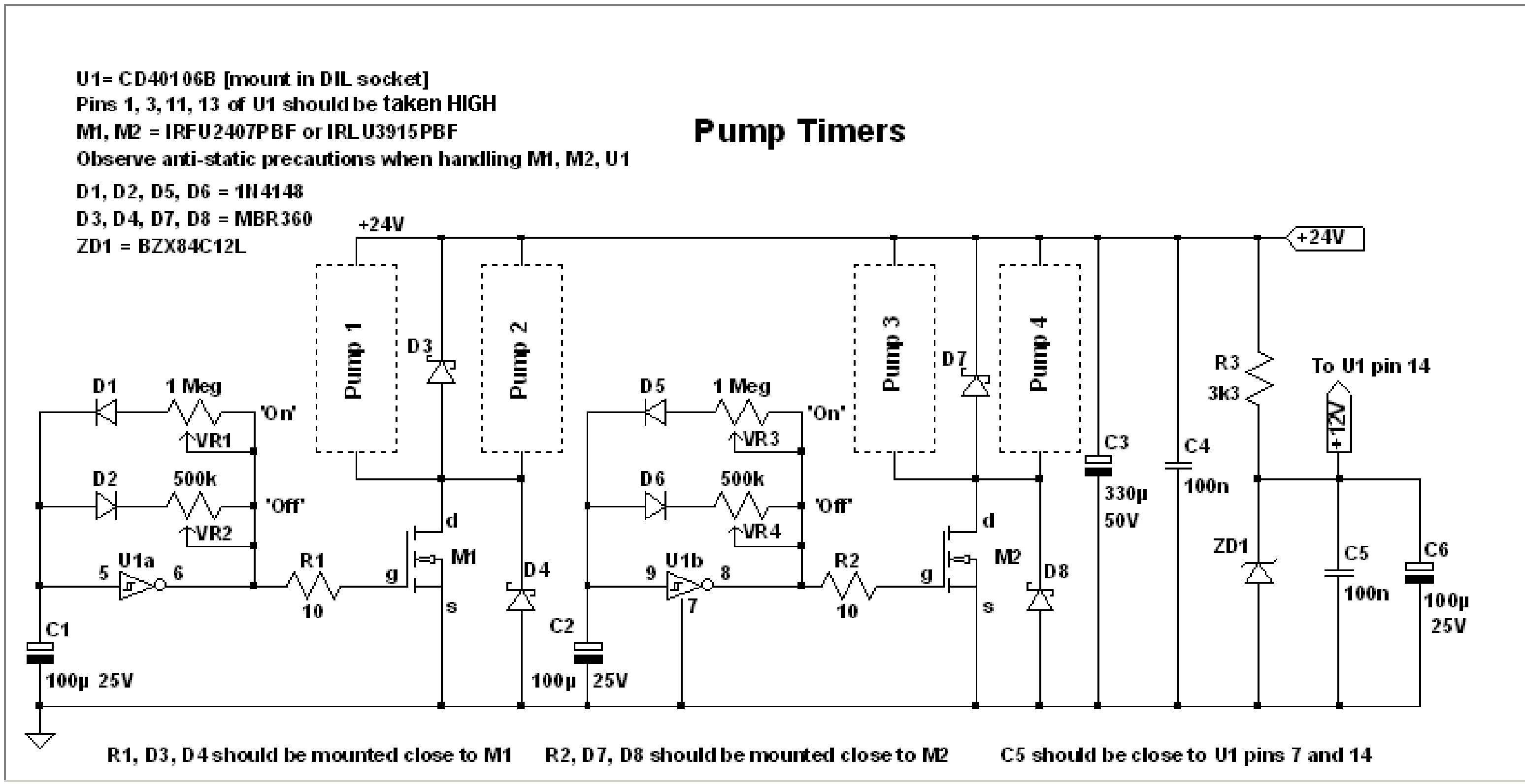


This circuit turns on the first relay for any period of time as determined by the value of C1 and R1. When relay 1 turns off, relay 2 turns ON for any period of time as determined by C2 and R2. When relay 2 turns off, relay 1 turns ON and the cycle repeats.

4 PUMPS

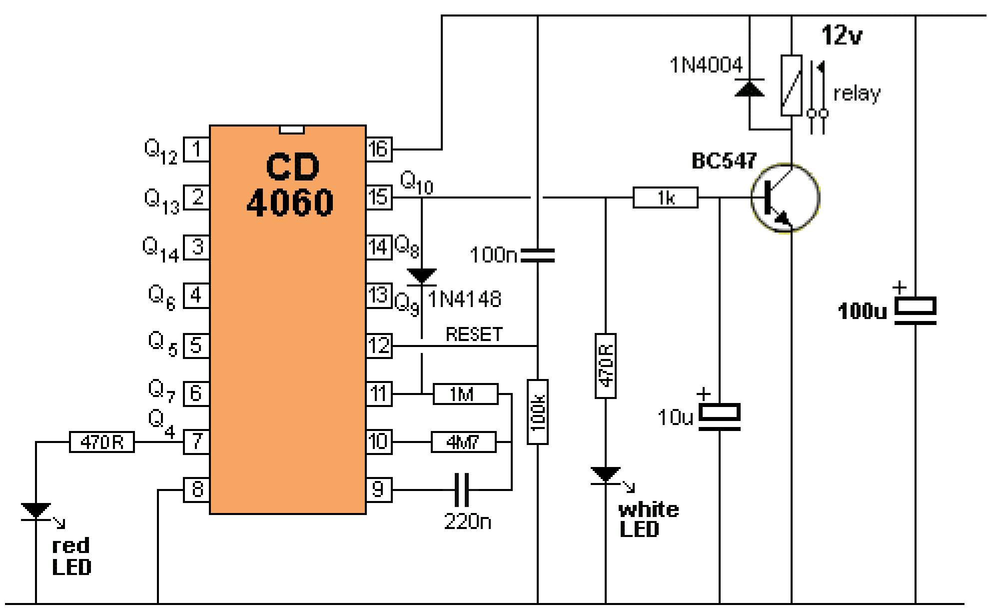
This circuit has been requested by a reader. He wanted 4 pumps to operate randomly in his water-fountain feature.
A 74C14 IC can be used to produce 4 timing circuits with different on-off values.
The trim-pots can be replaced with resistors when the desired effect has been created.





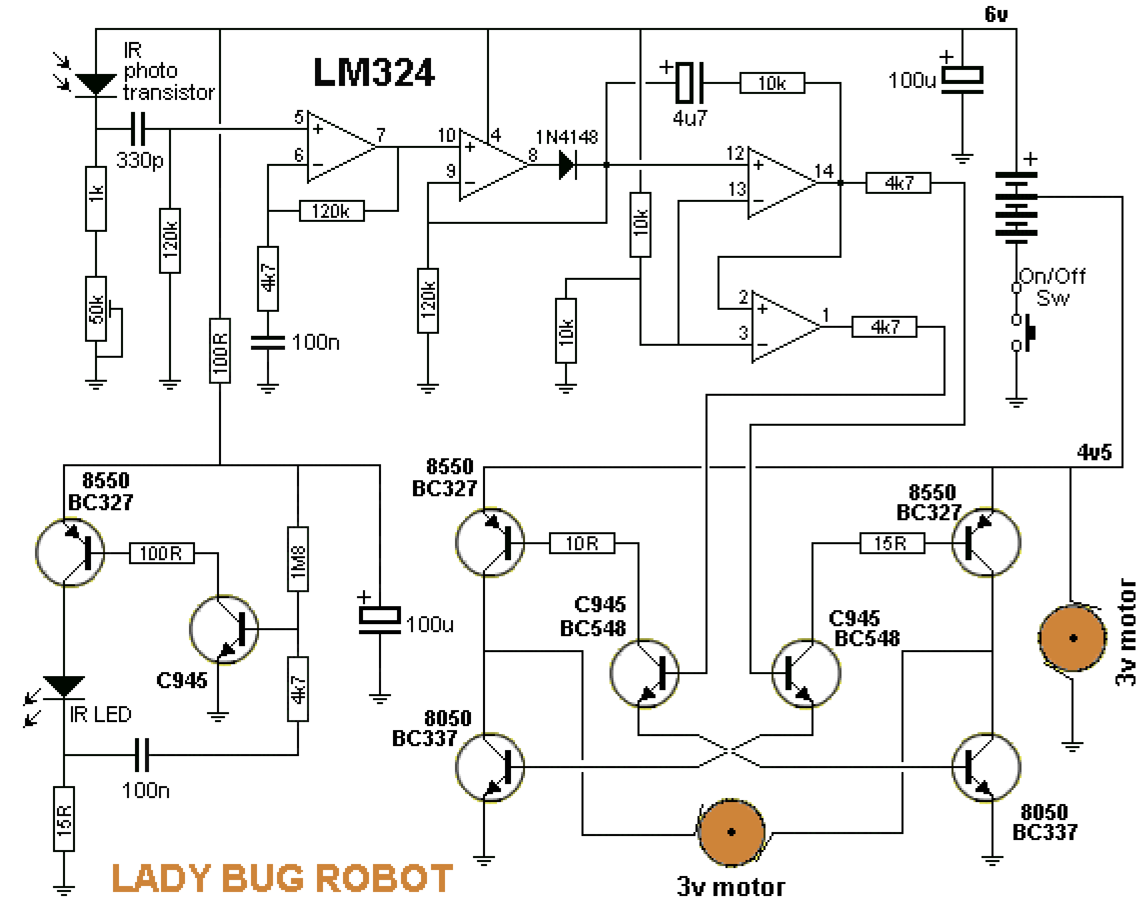
LONG DURATION TIMER

To get a long duration timer we can create an oscillator, called a CLOCK OSCILLATOR, and feed it to a number of flip-flops. A flip-flop is a form of bi-stable multivibrator, wired so an input signal will change the output on every second cycle. In other words it divides (halves) the input signal. When two of these are connected in a "chain" the input signal divides by 4. The CD4060 IC has 14 stages. These are also called BINARY DIVIDERS and the chip is also called a COUNTER.
The IC also has components (called gates or inverters) on pins 9,10 and 11 that can be wired to produce an oscillator. Three external components are needed to produce the duration of the oscillations. In other words the frequency of the "clock signal."
The output of the oscillator is connected (inside the chip) to the Binary Dividers and each stage goes HIGH then LOW due to the signal it is receiving. Each stage rises and falls at a rate that is half the previous stage and the final stage provides the long time delay as it takes 2^{13} clock cycles before going HIGH. We have only taken from Q10 in this circuit and the outline of the chip has been provided in the circuit so different outputs can be used to produce different timings.
The diode on the output "jams" the oscillator and stops it operating so the relay stays active when the time has expired.



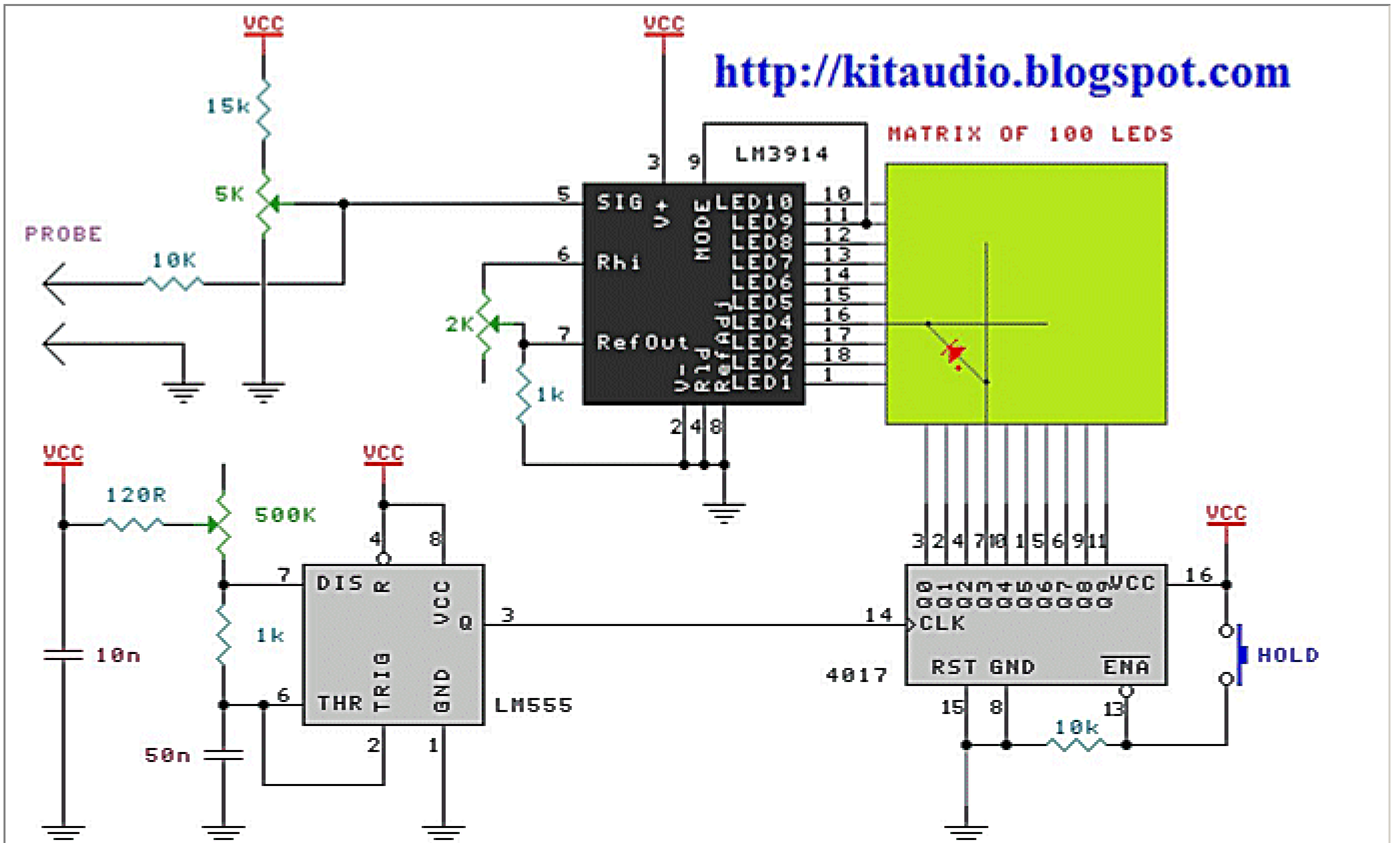
LADYBUG ROBOT

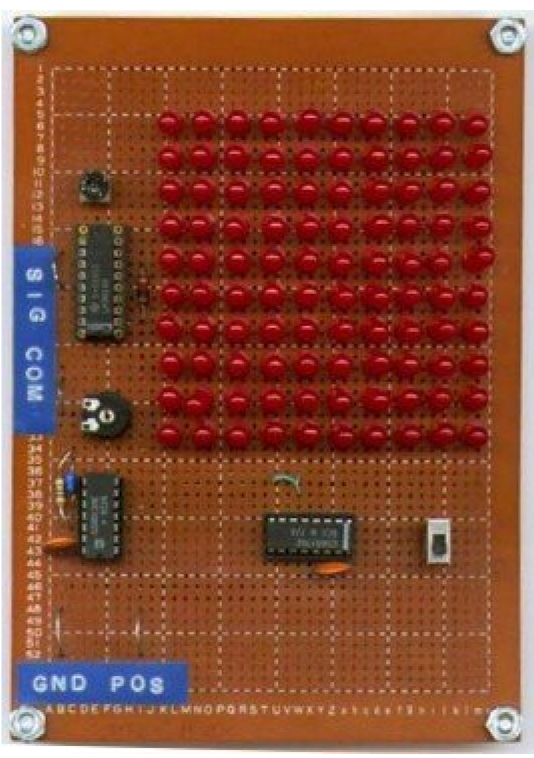
Ladybug Robot moves with its six legs and makes use of infrared emitting diodes as its eyes to avoid obstacles along its path. Ladybug automatically makes a left turn the moment it detects an object in its path. It continues to move forward again when no obstacle is in the way.



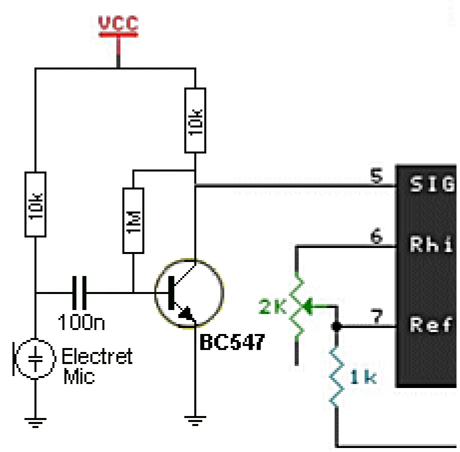
See **[Hex Bug](#)** in "200 Transistor Circuits" for a transistor version of this circuit.

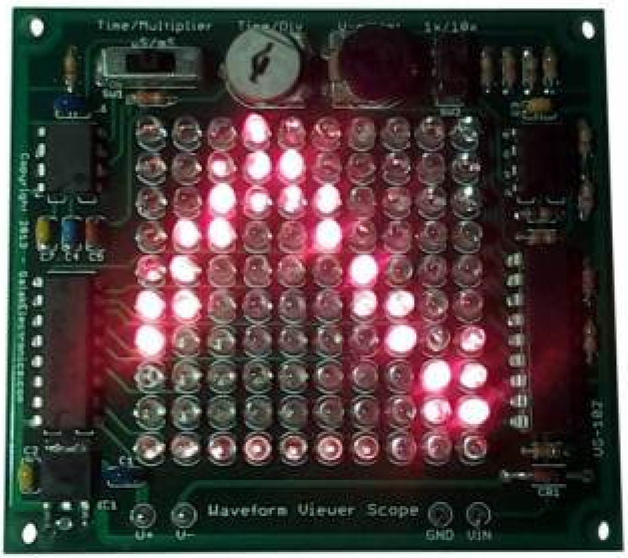
100 LED CRO





This circuit produces a "trace" on a set of 100 LEDs, just like a Cathode Ray Oscilloscope. It is only suitable for low frequency signals such as audio but can also reproduce low-frequency square waves. It's fun to talk into the microphone and see the result on the screen. Add the audio amplifier below to the input of the LM3914 dot/bar Display Driver (that has been set to dot-mode). To see a trace across the centre of the screen. The audio will raise and lower the trace to produce a waveform.
The photo on the right shows the authors model.





Here is a LED CRO kit on eBay. Cost is approx $20.00 for the kit and $7.00 postage.
More photos of PCB on eBay.
A very interesting kit and great educational value.

FEATURES:

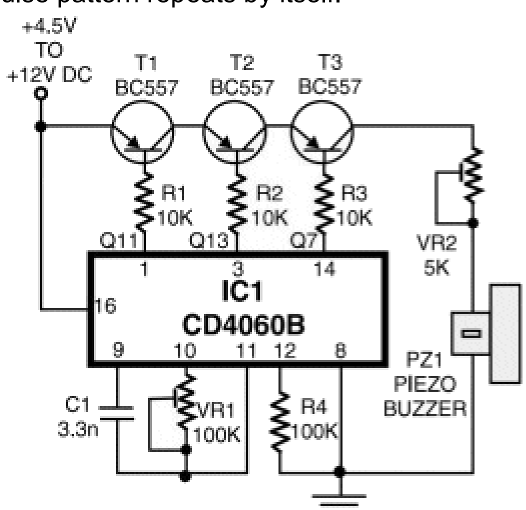
User selectable time scale from 120mS to 6.5µS with 3 ranges and time scale sweep control.
Scan rate of 150k samples per second for effective maximum frequency of 15kHz.
Operates from a single supply and can even be powered off a single 9V battery.
Two voltage scales and a full range voltage offset allows measurement of AC and DC signals.
Wide input supply voltage from 9VDC to 24VDC and a maximum supply current of only 28mA.

SPECIFICATIONS:

Supply Voltage: 9VDC to 24VDC @ 28mA
Time Scales: 125mS-Hz to 3.5mS; 4mS-125µS; 125µS-6.5µS (User selectable with slide switch and trim-pot)
Voltage Scales: 0-1V; 0-10V (User selectable with 2 position slide switch)
Voltage Offset: ±0.5V with 1X voltage scale; ±5V with 10X voltage scale

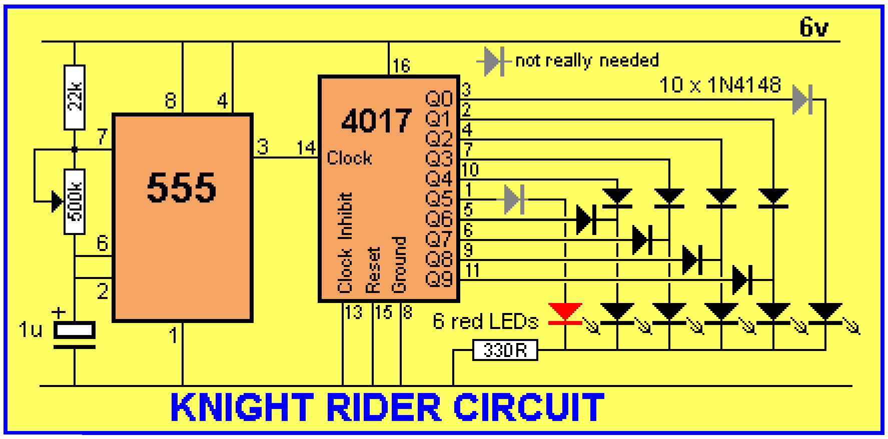
PHONE RINGER

This circuit shows how a very complex set of pulses can be produced via a very simple circuit. The CD4060B IC produce three kinds of pulses. Preset VR1 is fine-tuned to get 0.3125Hz pulses at pin 3 of IC1. At the same time, pulses obtainable from pin 1 will be of 1.25 Hz and 20 Hz at pin 14. The three output pins of IC1 are connected to base terminals of transistors T1, T2, and T3 through resistors R1, R2, and R3, respectively.
Working with a built-in oscillator-type piezo buzzer generates about 1kHz tone. In this particular circuit, the piezo-buzzer is turned ‘on’ and ‘off’ at 20 Hz for ring tone sound by transistor T3. 20Hz pulses are obtainable at the collector of transistor T3 for 0.4-second duration. Just after a time interval of 0.4 second, 20Hz pulses become again obtainable for another 0.4-second duration. This is followed by two seconds of no sound interval. Thereafter the pulse pattern repeats by itself.



KNIGHT RIDER

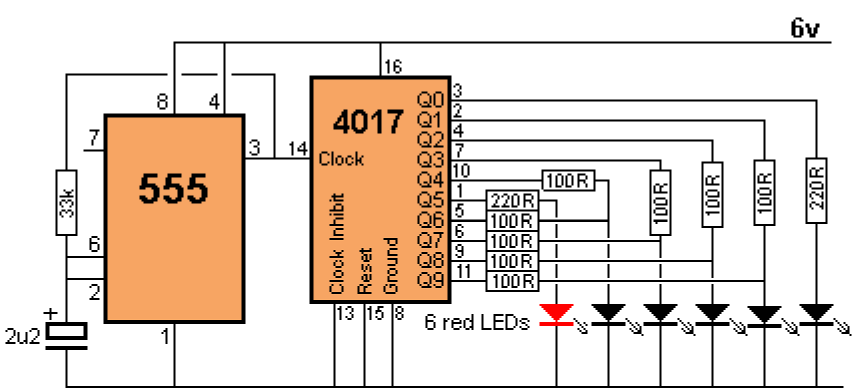
In the **Knight Rider** circuit, the 555 is wired as an oscillator. It can be adjusted to give the desired speed for the display. The output of the 555 is directly connected to the input of a Johnson Counter (CD 4017). The input of the counter is called the CLOCK line.
The 10 outputs Q_0 to Q_9 become active, one at a time, on the rising edge of the waveform from the 555. Each output can deliver about 20mA but a LED should not be connected to the output without a current-limiting resistor (330R in the circuit above).
The first 6 outputs of the chip are connected directly to the 6 LEDs and these "move" across the display. The next 4 outputs move the effect in the opposite direction and the cycle repeats. The animation above shows how the effect appears on the display.
Using six 3mm LEDs, the display can be placed in the front of a model car to give a very realistic effect. The same outputs can be taken to driver transistors to produce a larger version of the display.



KNIGHT RIDER CIRCUIT

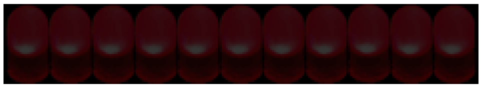
The **Knight Rider** circuit is available as a kit for less than $15.00 plus postage as **Kitt Scanner**.

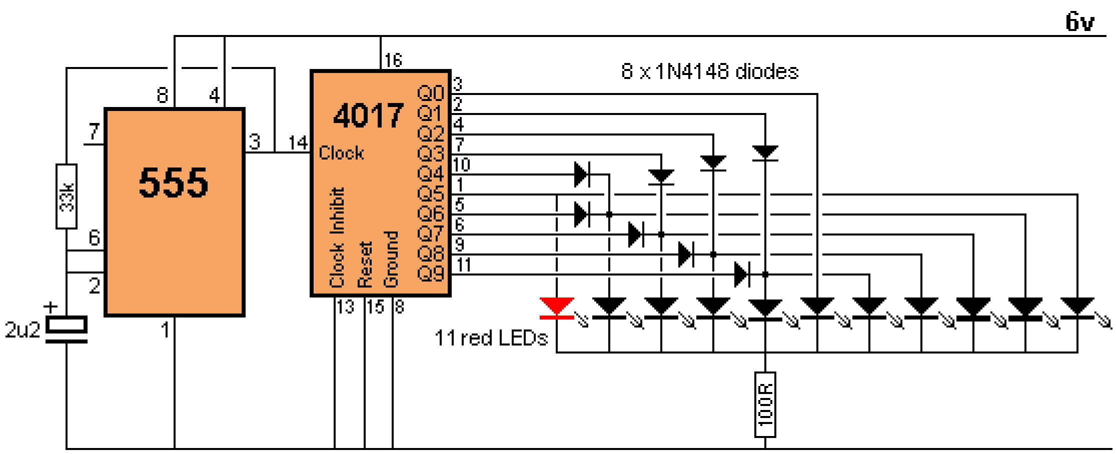
Here is a simple Knight Rider circuit using resistors to drive the LEDs. This circuit consumes 22mA while only delivering 7mA to each LED. The outputs are "fighting" each other via the 100R resistors (except outputs Q0 and Q5).



KNIGHT RIDER CIRCUIT-2

This circuit drives 11 LEDs with a cross-over effect:

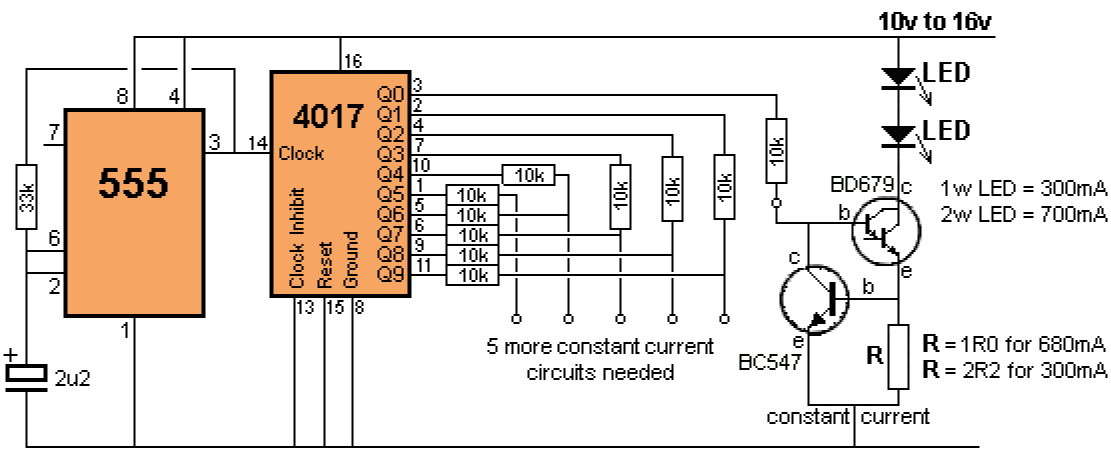




KNIGHT RIDER CIRCUIT - 3

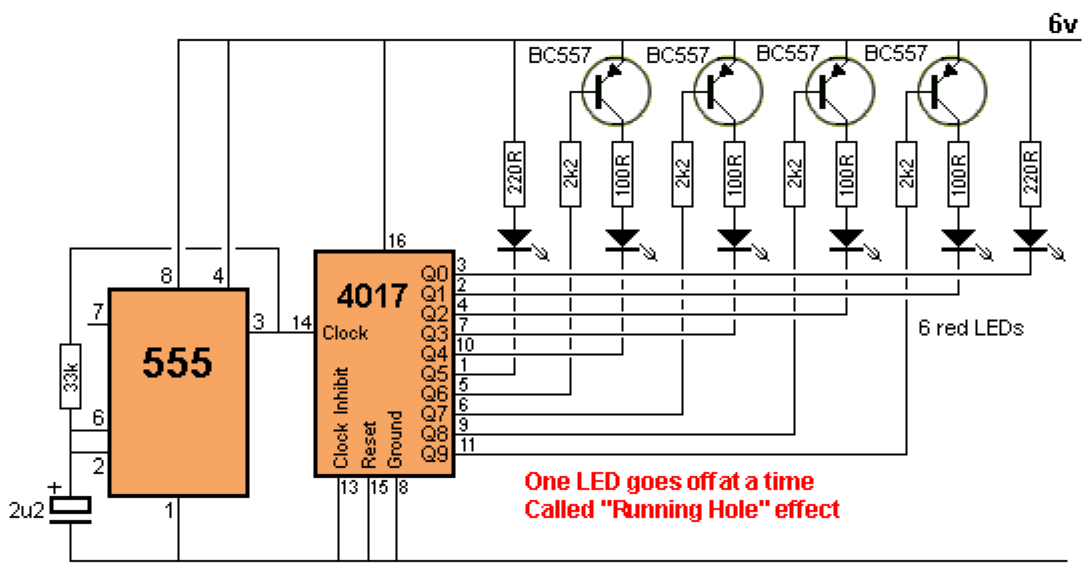
KNIGHT RIDER FOR HIGH-POWER LEDS (constant current)

This circuit provides constant current for high-power LEDs. The battery voltage for a car can range from 11v to nearly 16v, depending on the state-of-charge and the RPM of the engine. This circuit provides constant current so the LEDs are not over-driven.



KNIGHT RIDER FOR HIGH-POWER LEDS

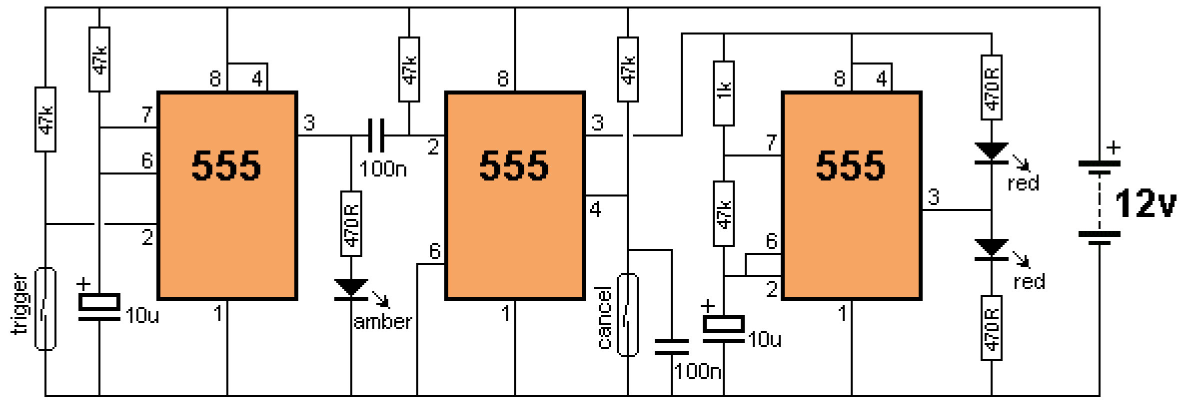
KNIGHT RIDER "RUNNING HOLE" EFFECT

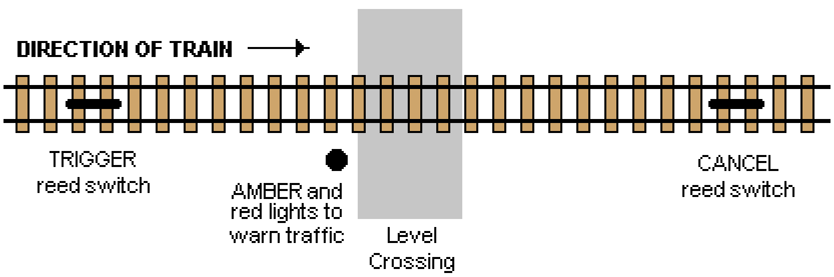


KNIGHT RIDER CIRCUIT - 5

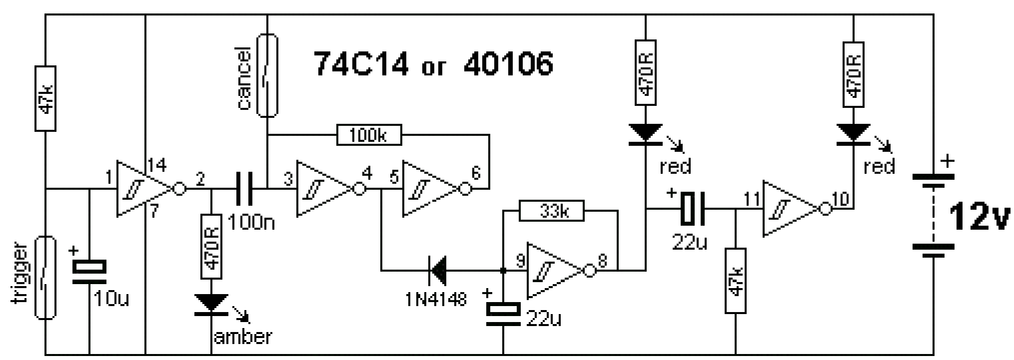
CROSSING LIGHTS

A magnet on the train activates the TRIGGER reed switch to turn on the amber LED for a time determined by the value of the first 10u and 47k.
When the first 555 IC turns off, the 100n is uncharged because both ends are at rail voltage and it pulses pin 2 of the middle 555 LOW. This activates the 555 and pin 3 goes HIGH. This pin supplies rail voltage to the third 555 and the two red LEDs are alternately flashed. When the train passes the CANCEL reed switch, pin 4 of the middle 555 is taken LOW and the red LEDs stop flashing.
See it in action: Movie (4MB)



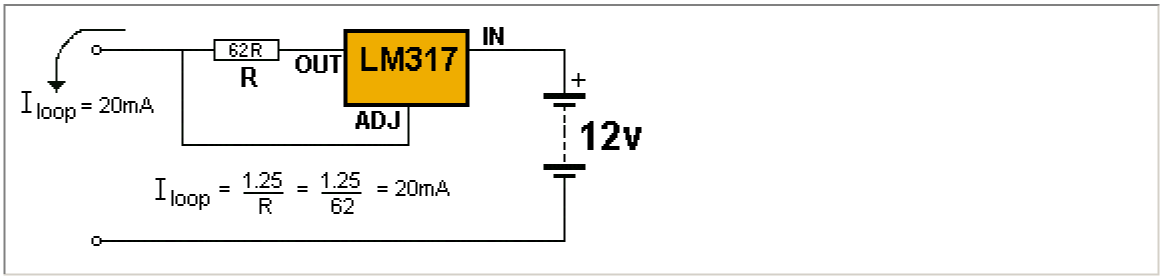


The circuit can also be constructed with a 40106 HEX Schmitt trigger IC (74C14). The 555 circuit consumes about 30mA when sitting and waiting. The 40106 circuit consumes less than 1mA.



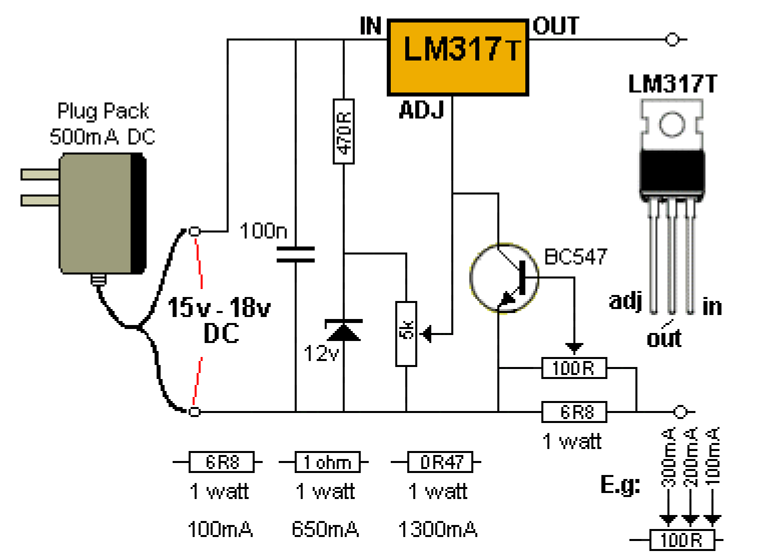
20mA CONSTANT-CURRENT GENERATOR

This circuit produces a constant 20mA current with an output voltage approx 3v lower than the battery voltage.
It uses an LM317 adjustable regulator which has a voltage-drop of about 3v between the IN and OUT terminals. If the battery voltage is 12v, the circuit will deliver about 9v at 20mA. The regulator has an internal voltage reference of 1.25v between OUT and ADJUST pins and when a resistor is placed between the OUT pin and the circuit being supplied, the current flowing through the resistor will produce a voltage-drop. As the current required by the circuit increases, the voltage across this resistor will increase. When it is 1.25v, the current will be 20mA. If the current increases due to the output resistance decreasing, the voltage across the resistor increases and the LN317 reduces the output voltage. This causes the current to reduce to 20mA. This is how the circuit produces a constant current.
The output current can be changed to any value according to the formula shown below.



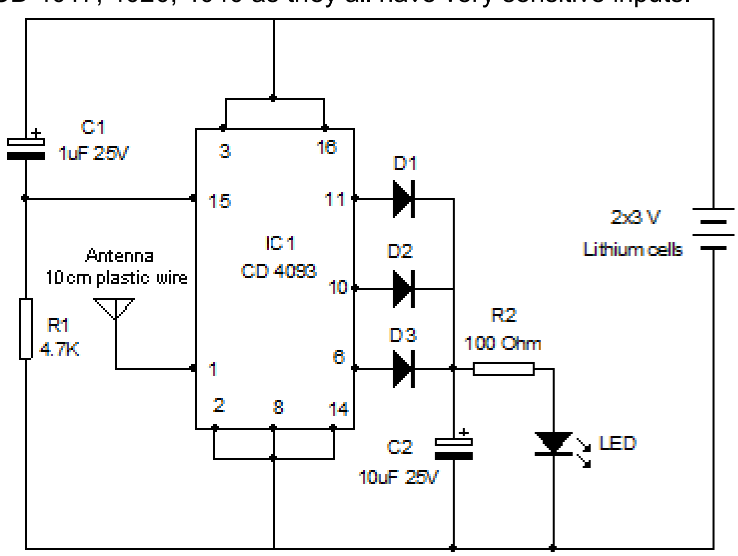
ADJUSTABLE VOLTAGE AND CURRENT LIMITING

The single regulator in this circuit will provide a variable voltage from 1.225v to 12v or more, depending on the voltage of the plug pack and the zener diode. The current will also depend on the rating of the plug pack.
As soon as the current reaches the limit set by the 100R pot, the BC547 transistor starts to turn on and rob the regulator of voltage on the Adj pin. The output voltage starts to reduce. If the output is shorted, the output voltage will reduce to almost zero.

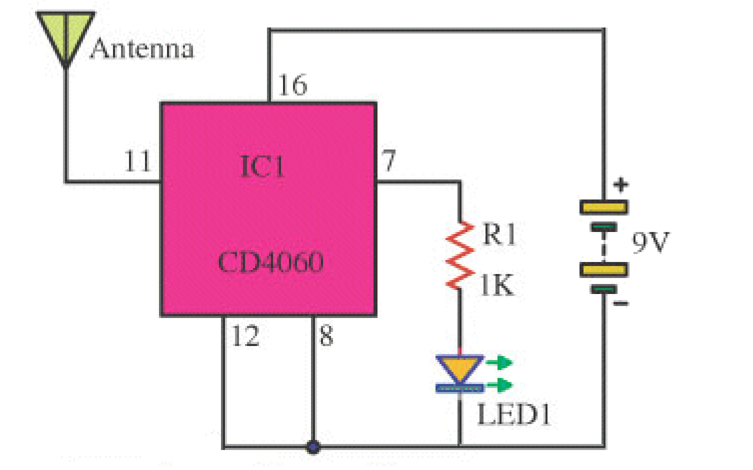


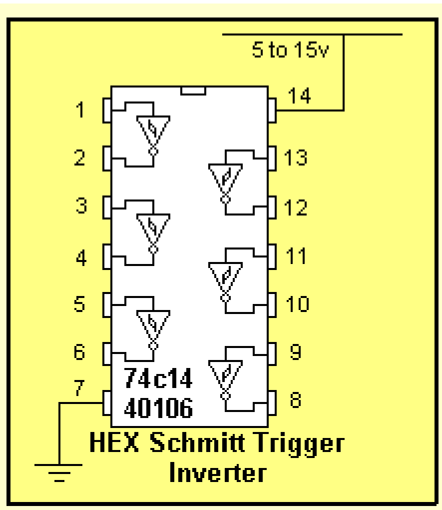
MAINS DETECTOR

This circuit will detect active mains at 15cm. Mains wiring must not be touched. Many CMOS chips can be used for this purpose.
CD 4017, 4020, 4040 as they all have very sensitive inputs.



This circuit will also detect "Mains Hum." It is the simplest circuit and will work on 6v - 9v. Use a small length of copper-clad PC board 1cm wide for the detector. DO NOT TOUCH ANY WIRES or cables. The LED will flash when the antenna is 10cm to 15cm from the cable.





THE 74c14 IC - also known as 40106 or 40014 - it works on 5v to 15v.

[But not 7414 or 74HC14 or 74HCT14 or 74LS14 as these IC's are for 5v supply ONLY.
They are TTL chips and operate on 4.5v to 5.5v and have low impedance inputs.]

The **74c14 IC** is one of the most useful chips on the market. When you realise its versatility, you will use it for lots of designs.
In this section we describe its capability and provide circuits to show how it can be used.

The 74C14 IC contains 6 Schmitt Trigger gates.
Minimum supply voltage 5v
Maximum supply voltage 15v
Max current per output 10mA - 60mA total
Maximum speed of operation 4MHz
Current consumption approx 1uA with nothing connected to the inputs or outputs.

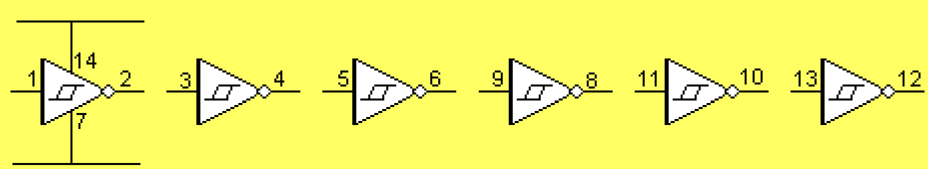
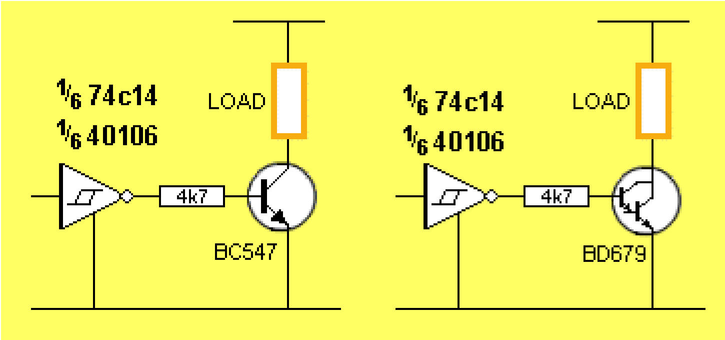


Fig: 8 The six Schmitt Trigger Gates for a 74c14 IC

The output of each gate will deliver about 10mA. This is sufficient to drive a LED, but if extra current is required, a transistor BUFFER will be needed. For up to 100mA, a BC547 can be used. For up to 4 amps a BD679 Darlington transistor can be used.



Adding a BUFFER TRANSISTOR

Each gate is a separate "Building Block." It is basically an AMPLIFIER. It is a CURRENT AMPLIFIER and it is different to any other type of amplifier. Here is how it works:
When the input is LOW, the output is HIGH and will deliver 10mA to a load. When the input is HIGH the output is LOW and it will sink 10mA from a load that is connected to rail.
Here is the CURRENT AMPLIFYING part: It takes less than 1 microamp on the input to make the output high or low.
Here's the second feature of the gate:
When the input is LOW (A LOW is from 0v to 25% of rail voltage), it can be increased slowly or up to a frequency of 4MHz, and when the voltage is 66% of rail voltage, the output immediately changes from HIGH to LOW.
When the input is HIGH (from 70% to 100% of rail voltage) and it decreases slowly or up to a frequency of 4MHz, the output immediately changes from LOW to HIGH when the voltage drops to 33% of rail voltage.
This produces a GAP between 33% and 66% called the HYSTERESIS GAP and it prevents noisy input voltages changing the output. The input voltage has to rise and/or fall about 33% of rail voltage for the output to change.
There are 6 of the gates in the IC and they are all internally wired to the power rails. You can think of the input as having infinite impedance (resistance), so it does not put a load on anything connected to this pin.

Here is an animation of how the gate works. The input has to be above mid-rail for the output to change and below mid-rail for the output to change back to its originals state.

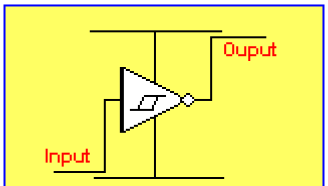
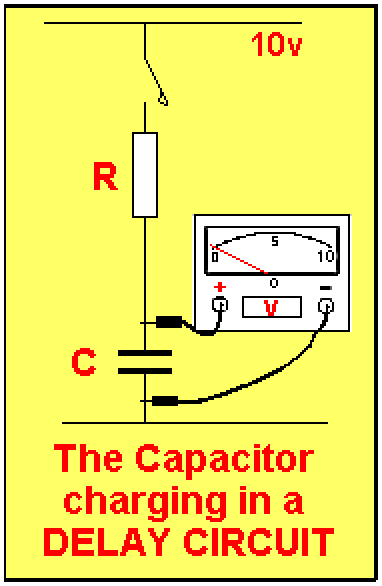
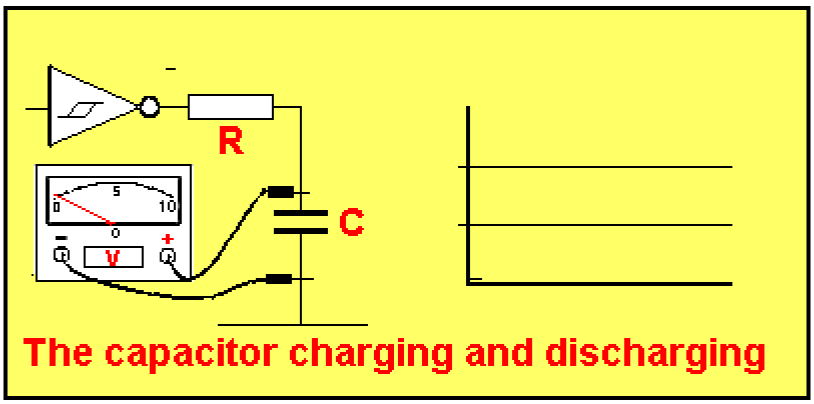


Fig: 4 The Schmitt Trigger

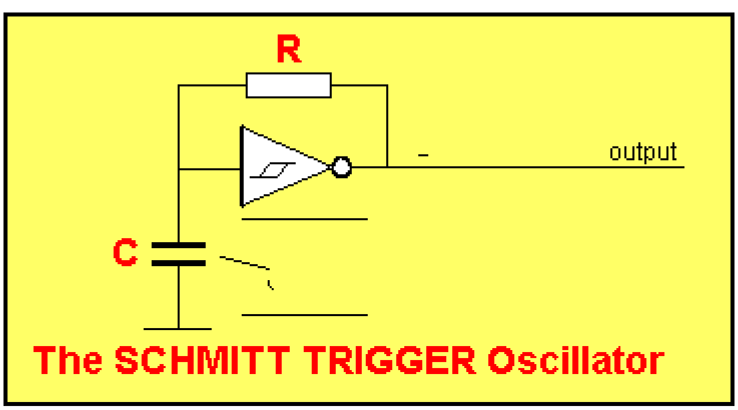
The next feature to understand is called **THE TIME DELAY CIRCUIT**
The time delay circuit is also know as a "**TIMING CIRCUIT**," "**DELAY CIRCUIT**," or "**R-C CIRCUIT**". These names all refer to a CAPACITOR and RESISTOR in series. It does not matter if the capacitor is placed above or below the resistor as the **time delay** will be the same. (The only difference will be the value of the voltage at the beginning and end of the timing cycle.)
The join of the two components is the point where the voltage is detected and is called the "**Detection Point**."
The Detection Point is monitored by a **Detection Circuit**. This will be the input of one of the Schmitt gates.
The detection circuit **must not load** the timing circuit. In other words the detection circuit must have a very high input impedance. That's the advantage of this IC. It is ideal for detecting the voltage on a DELAY CIRCUIT.
When voltage is applied to a TIMING CIRCUIT, the capacitor begins to charge. If we monitor the voltage across the capacitor, we can determine when it is at a particular voltage level. It will take a PERIOD OF TIME to reach this level and this is the TIME DELAY we require.
In the animation below we see the capacitor charging via a resistor, with a meter showing the approx voltage across the capacitor. The capacitor does not charge at a constant rate, but this characteristic does not concern us at the moment.
The point to remember is the TIME it takes for the capacitor to charge.



If we add the TIMING CIRCUIT (DELAY CIRCUIT) to the output of a Schmitt gate, we can see the capacitor charging and discharging:



Here is the clever part. Instead of the voltmeter monitoring the voltage across the capacitor, the input of the Schmitt Inverter can be connected to the capacitor.
If the voltage across the capacitor is less than 66% of rail voltage, the output of the gate is HIGH and the capacitor begins to charge. When the voltage reaches 67%, the output goes LOW and the capacitor begins to discharge. When the voltage across it reaches 32% of rail voltage, the Schmitt Inverter changes state and the output goes HIGH. In this way we need only one gate to create an oscillator.
There are two very important things to observe in the animation below.
1. The output is a square wave. In other words the output goes from one state to the other **VERY QUICKLY** and this produces the characteristic square wave-shape.
2. The voltage across the capacitor is EXACTLY 32% to 67% of rail voltage.
The animation below shows the gate in operation.
You will notice that the diagram does not show the chip connected to the positive and negative rail. It is **ASSUMED** the chip is connected to the supply voltage and that's how the output produces the HIGH.



Here are the basic oscillator blocks for a 74C14 (40106) IC:

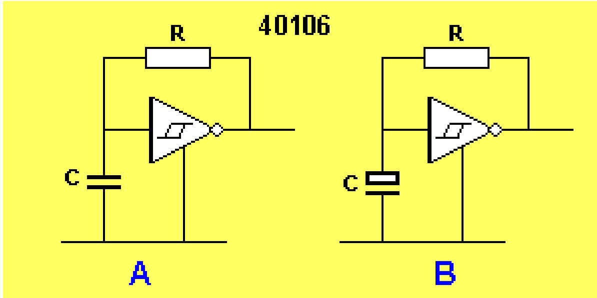
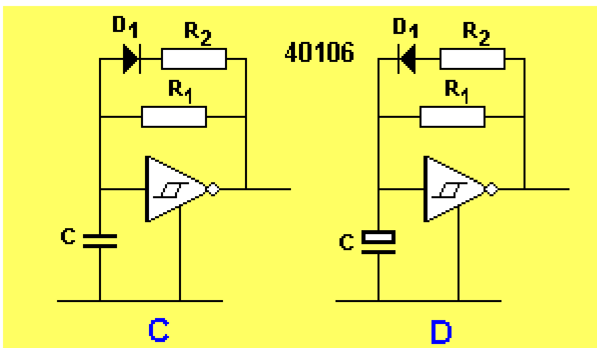


Fig A shows a capacitor - high frequency oscillator
Fig B shows an electrolytic - low frequency oscillator

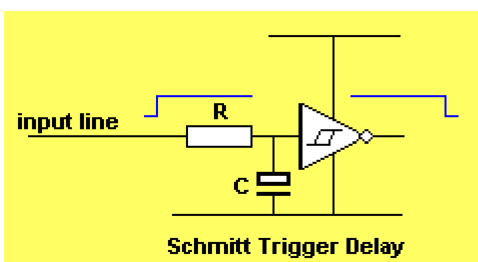
An oscillator is created by placing a resistor from output to input and a capacitor from input to 0v. The output will be a square-wave and and the mark (high) will be equal to the space (low).
The frequency of the output will depend on the value of R and C. Values of 1k to 4M7 for R and 100p to 100u for C can be used. This is shown in circuits A and B above.

If an unequal HIGH and LOW is required, a diode is placed between output and input:



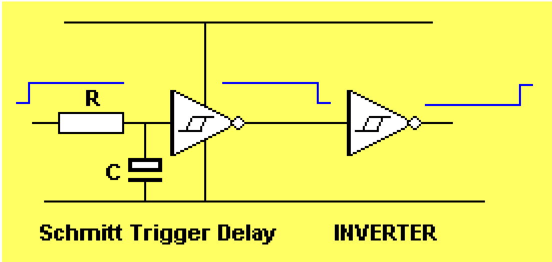
In figure C the output is output is low for a short period of time as the two resistors R1 and R2 are discharging the capacitor. If R2 is a very low value compared with R1 we can get the low duration to be 10% or less, of the HIGH.
In figure D the diode is reversed compared to figure C and output is high for a short period of time as the two resistors R1 and R2 are charging the capacitor.

Here are some basic building blocks:

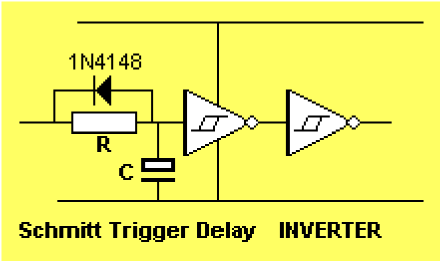


Delay

In the diagram above, the **input line** goes HIGH and remains HIGH. It can be detecting a piece of equipment being turned on, for example.
This action charges capacitor **C** via resistor **R**. After a period of time (called the Delay Time), the input of the Schmitt Trigger reaches 67% of rail voltage and the output goes LOW.
The Delay Time is determined by the values of R and C. We are not concerned with the actual values of R and C at this point in time. They can be worked out by experimentation.
The point to note is the placement of the two components to produce a **DELAY**.
If the output is required to be the opposite of the circuit above, an inverter is added:

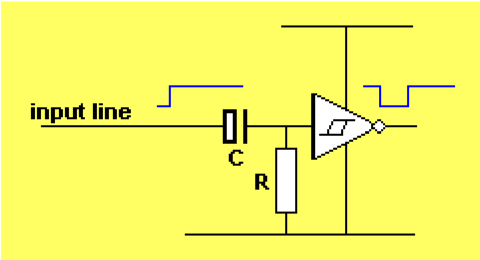


If a diode is added across the input resistor, the capacitor "C" will be discharged when the input goes low, so the "Delay Time" will be instantly available when the input goes HIGH:

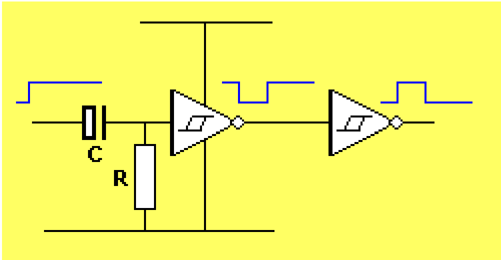


Pulse

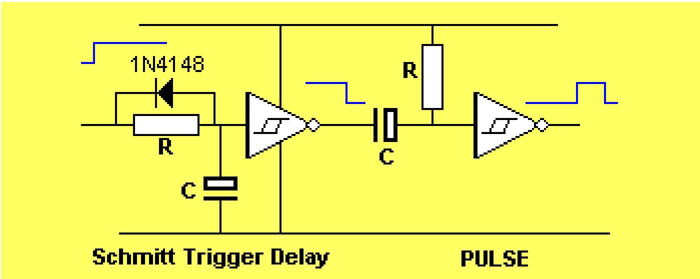
The following circuit produces a PULSE when the **input line** goes HIGH:



To invert the output, add an inverter:

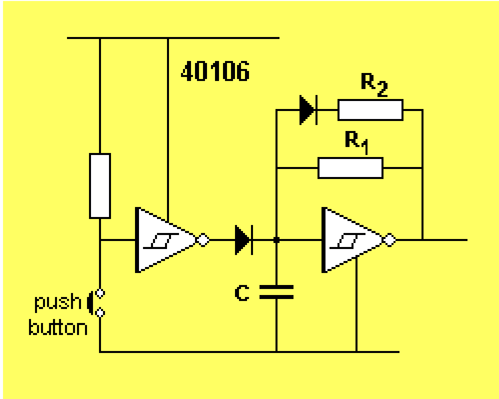


To produce a pulse after a delay, the following circuit is required:



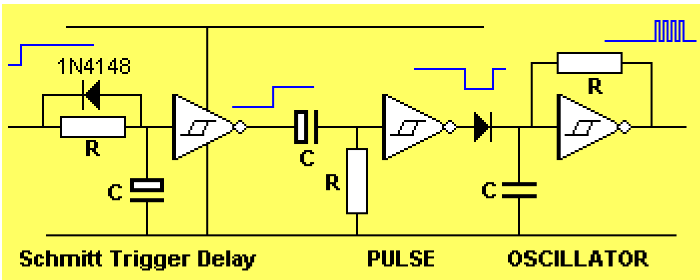
Gating

To gate an oscillator via another inverter, a diode is placed between the two gates:

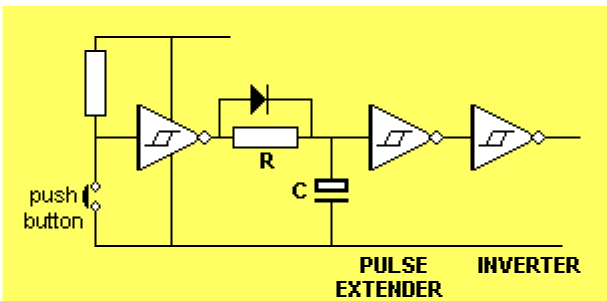


When the push-button is pressed, the input of the first gate goes LOW and the output goes HIGH. The high from the diode prevents the capacitor discharging via the oscillator and it is "jammed" or "frozen" with the output LOW.

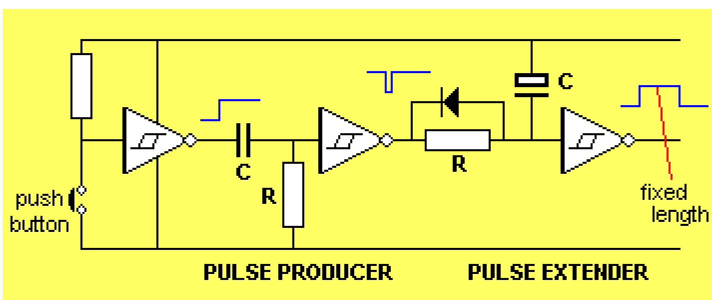
The following circuit produces a tone for a short period of time as determined by the pulse section. When the output of the Pulse section is LOW, the oscillator will operate. When the Pulse section is HIGH the oscillator is JAMMED.



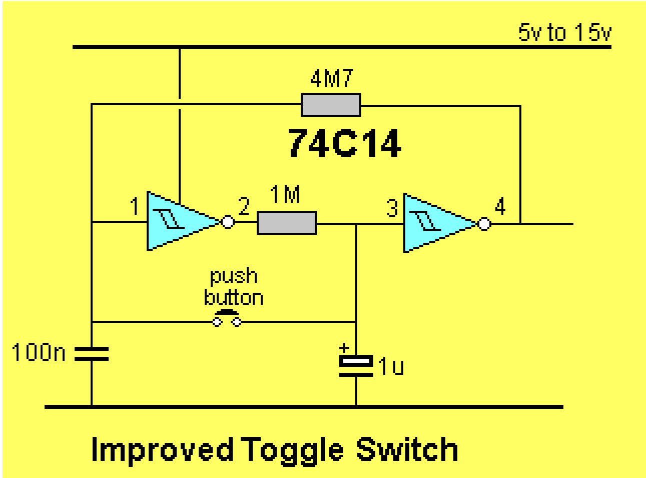
To extend the action of a push button, a pulse-extender circuit can be added:



To produce a pulse of constant length, (no matter how long the button is pressed), the following circuit is needed:

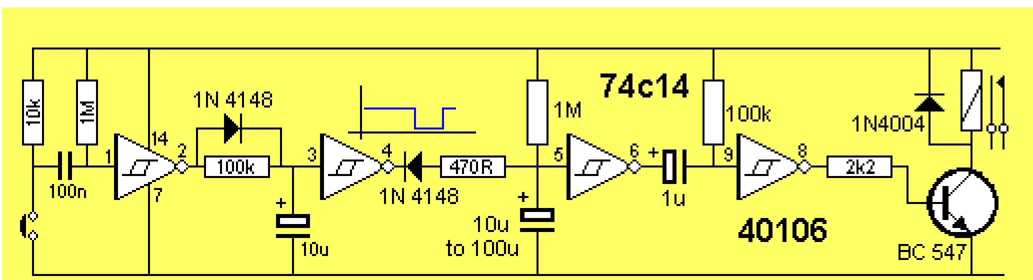


To produce a TOGGLE SWITCH, the following circuit is needed.
The input of the 40106 has a microscopic current availability and over a period of a few hours it will charge the 100n and cause the circuit to re-trigger. That's why the 4M7 is needed.



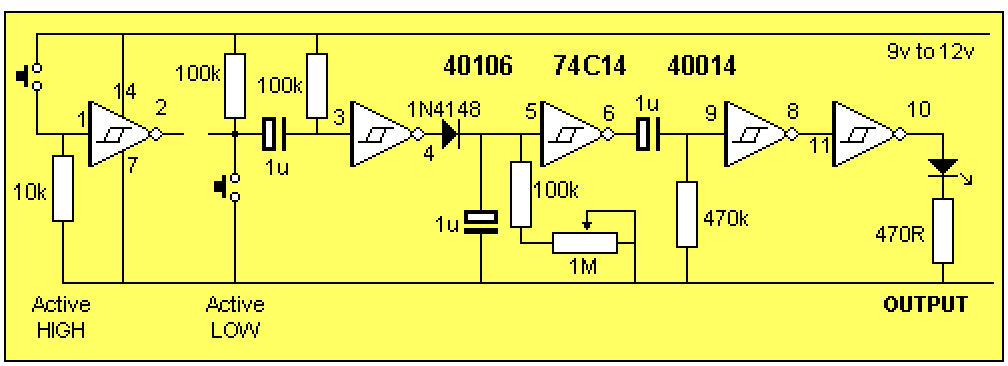
2 MINUTE TIMER

The relay is energized for a short time, 2 minutes after the push-button is pressed. The push-button produces a brief LOW on pin 1, no matter how long it is pushed and this produces a pulse of constant length via the three components between pin 2 and 3. This pulse is long enough to fully discharge the 100u timing electrolytic on pin 5. The 100k and electrolytic between pins 6 and 9 are designed to produce a brief pulse to energize the relay.



Produces a short pulse after 2 minutes

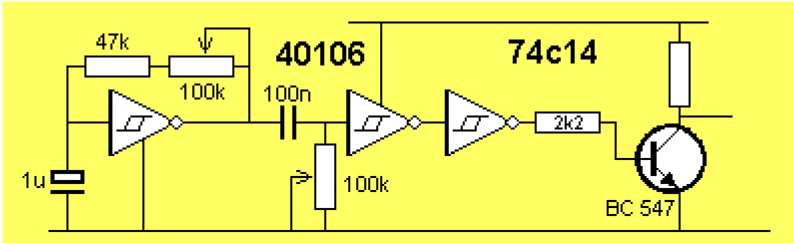
Here is another very similar circuit. Use either the active HIGH or Active LOW switch and if the Active LOW switch is used, do not connect the parts or gate between pins 1 and 2 to the rest of the circuit.



Produces a 0.25sec pulse after 0.1sec to 2 seconds

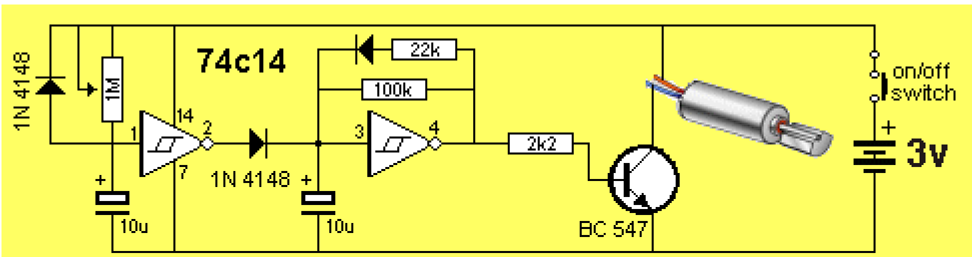
PULSER

The 74c14 can be used for lots of different circuits. In the following design, the output produces 3mS pulses every second. The circuit is adjustable to a wide range of requirements.



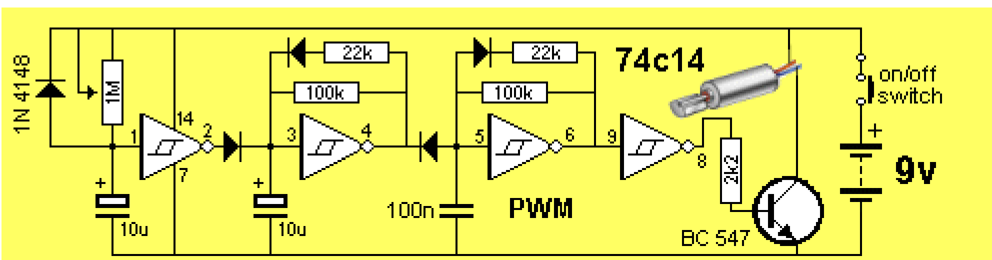
Produces (3mS wide) pulses per sec

This circuit pulses the pager motor about 2 - 4 seconds after the circuit is turned on:



Produces short pulses after 2- 4 seconds

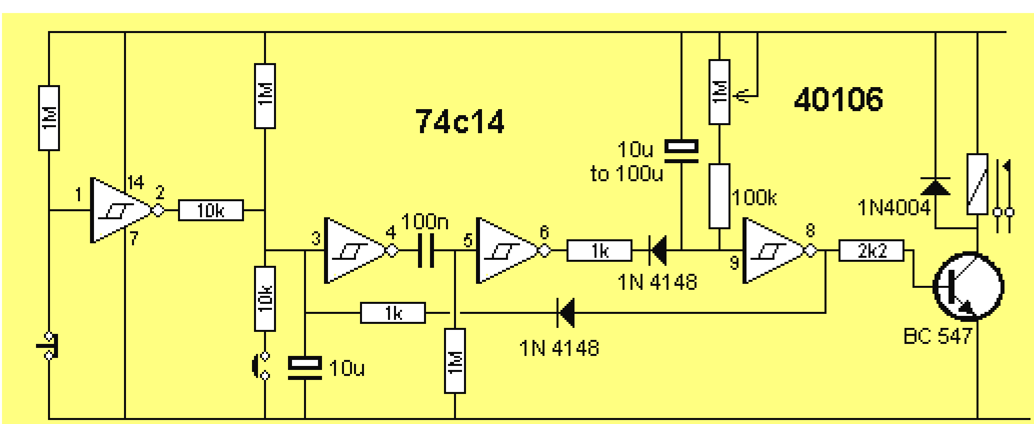
The following circuit allows a higher voltage to be used and PWM controls the energy to the Pager Motor. The component values will have to be determined by experimentation:



Produces short pulses after 2- 4 seconds

TRIGGER TIMER

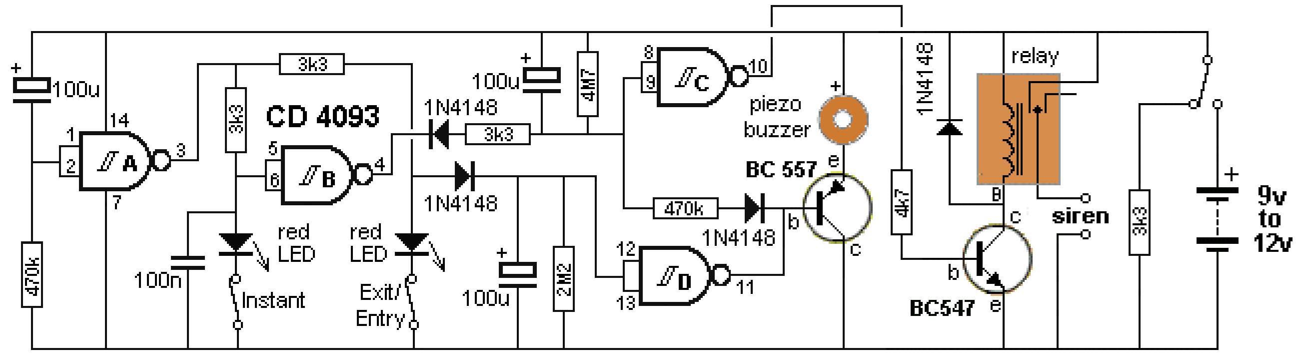
The next design interfaces a "Normally Open" and "Normally Closed" switch to a delay circuit.
The feedback diode from the output prevents the inputs re-triggering the timer (during the delay period) the so that a device such as a motor, globe or voice chip can be activated for a set period of time.

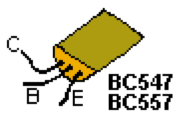


TRIGGER TIMER

2-SECTOR HOME ALARM

This alarm circuit only has one fault. The alarm keeps wailing if the door is kept open. It only turns off after 5-10 minutes when the door is closed.
The CD4093 is a **quad 2-input NAND gate** and each is wired as an inverter in this circuit.
The first gate "**A**" is a timer and the output does not go HIGH until the 100u charges via the 470k. This is the Exit/Entry delay. When it goes HIGH, the two LEDs are turned ON via the 3k3 resistors. This arms the alarm.
Gate "**B**" is an inverter that detects when the Instant input is broken and it charges the 100u via the 3k3 resistor.
Gate "**C**" detects the charge on the 100u and turns on the BC547 transistor via the 4k7 resistor.
The 100u and 4M7 provide the 5-10 minutes timer for the "wailing."
The 100u and 2M2 provide the timer provide the timer for the buzzer when you enter. It will buzz for 20 seconds then turn off. If the Entry door is left open, the main siren will wail after 45 seconds.

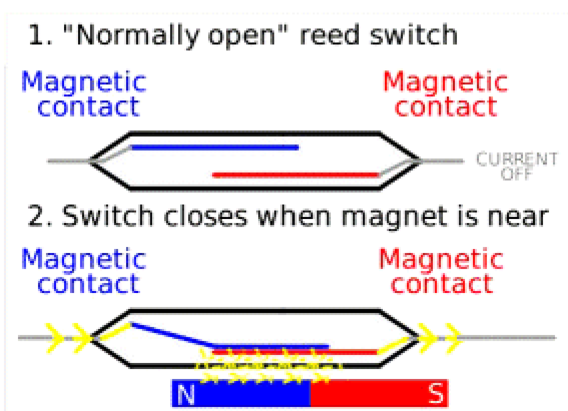




2-SECTOR HOME ALARM

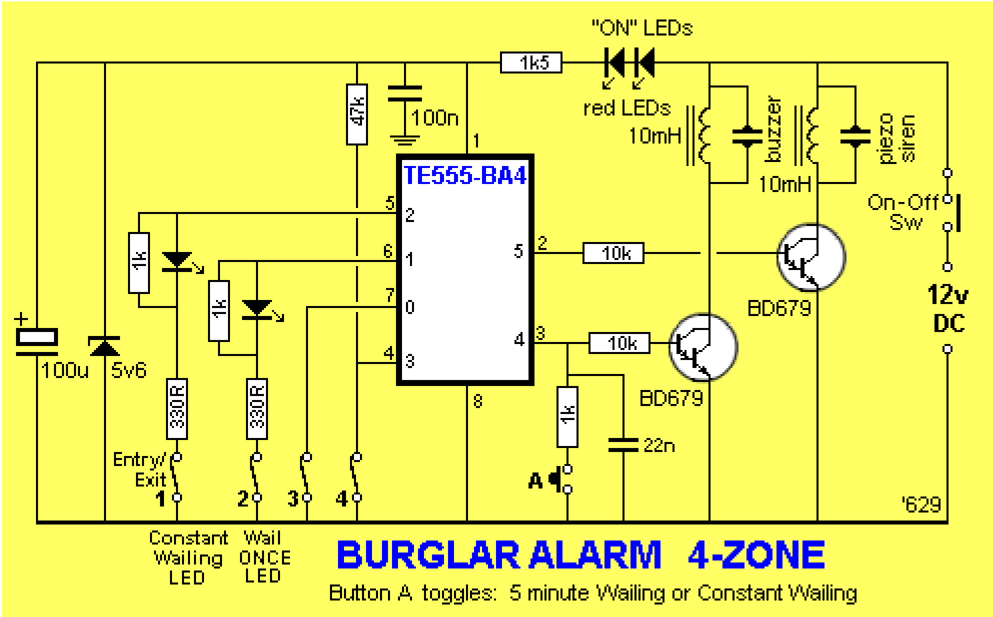
BURGLAR ALARM 4-ZONE

This circuit uses a dedicated alarm chip from Talking Electronics (**TE555-BA4**). The chip costs $2.50 and contains a 4-zone Burglar Alarm circuit. All you need are the surrounding components to complete the project. These components are available as a kit for $20.00 including the dedicated chip and this makes it one of the cheapest kits on the market (postage for kit $6.50). Click HERE to order the chip or the kit.
The only additional parts you require are 4 reed switches. These can be purchased on eBay for $5.38 for a set of 5 Normally Open switches (post free).
Here is the link:
http://www.ebay.com/itm/5-Set-Door-Or-Window-Safety-Contact-Magnetic-Alarm-Reed-Switch-NO-with-Screws-/290746194636?pt=LH_DefaultDomain_0&hash=item43b1d2dacc



Build the circuit on a piece of matrix board (or the Circuit Board included in the kit) and connect the inputs to the screw terminals. 6 separate 2-screw terminals are provided in the kit to make it easy to wire-up the alarm. The alarm takes about 1mA when monitoring a house and about 100mA when activated.
The siren is only activated ONCE for 5 minutes when a break-in occurs as this is the maximum allowable time for a siren to wail in Australia.
If you want the alarm to constantly wail after a break-in, push button A when the alarm is turned on (and the exit beep is being produced). The constantly wailing LED will flash. Push the button again and the 5 minute LED will flash. The button toggles between the two features.

You can use reed switches for the input devices for doors and drawers. You can also trap the burglar by placing money under a clip and have a very thin length of tinned copper wire wound around two pins. When the money is removed, the wire is pulled off the pins. A single strand of wire can be obtained from a length of hook-up flex.



POWER SUPPLY

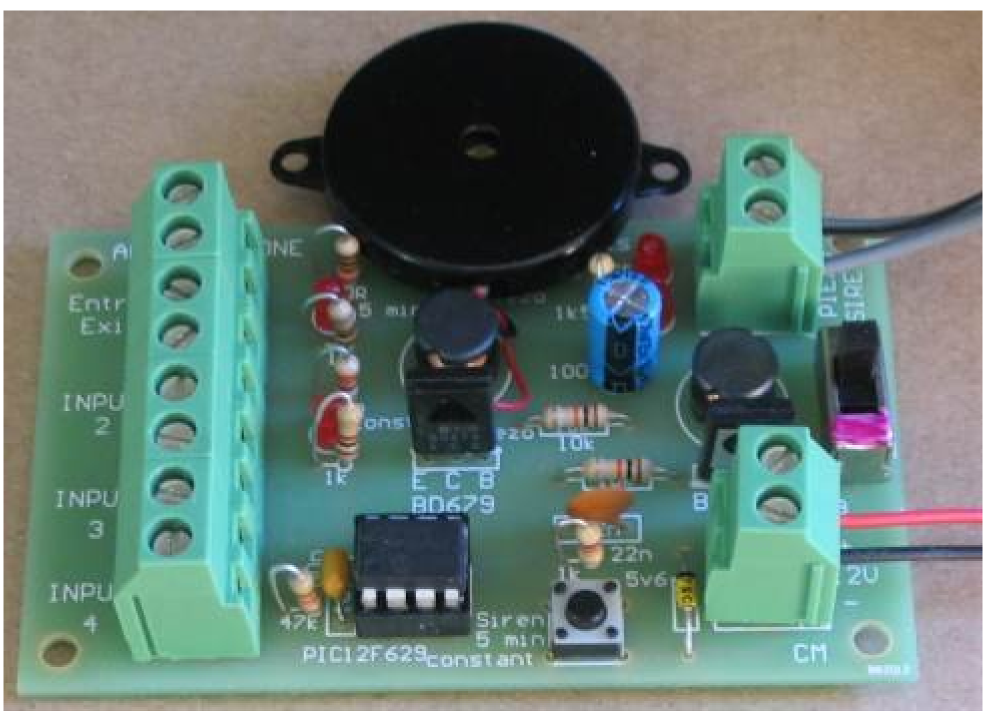
The alarm can be connected to a 12v gell cell with a rating of 1.2AHr and it can be automatically charged using our

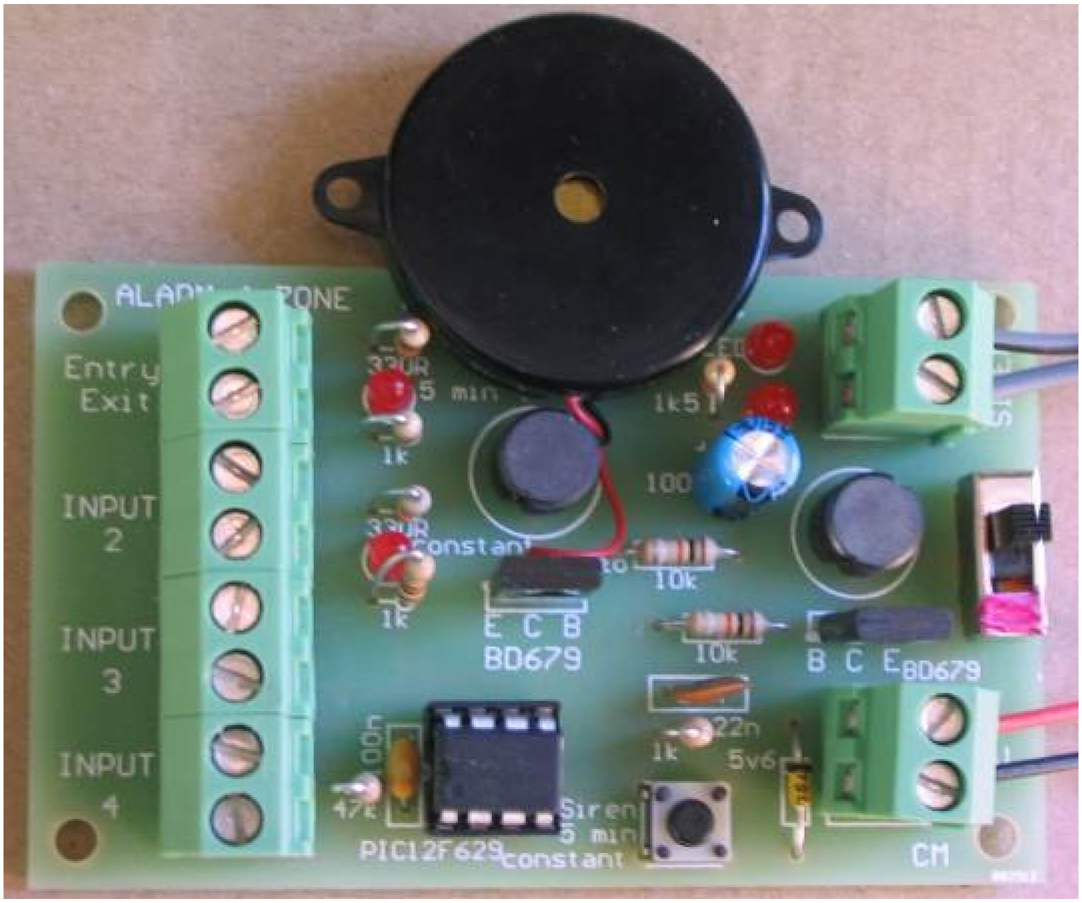
Automatic Battery Charger in 101 Transistor Circuits.

http://www.talkingelectronics.com/projects/200TrCcts/101-200TrCcts.html#84

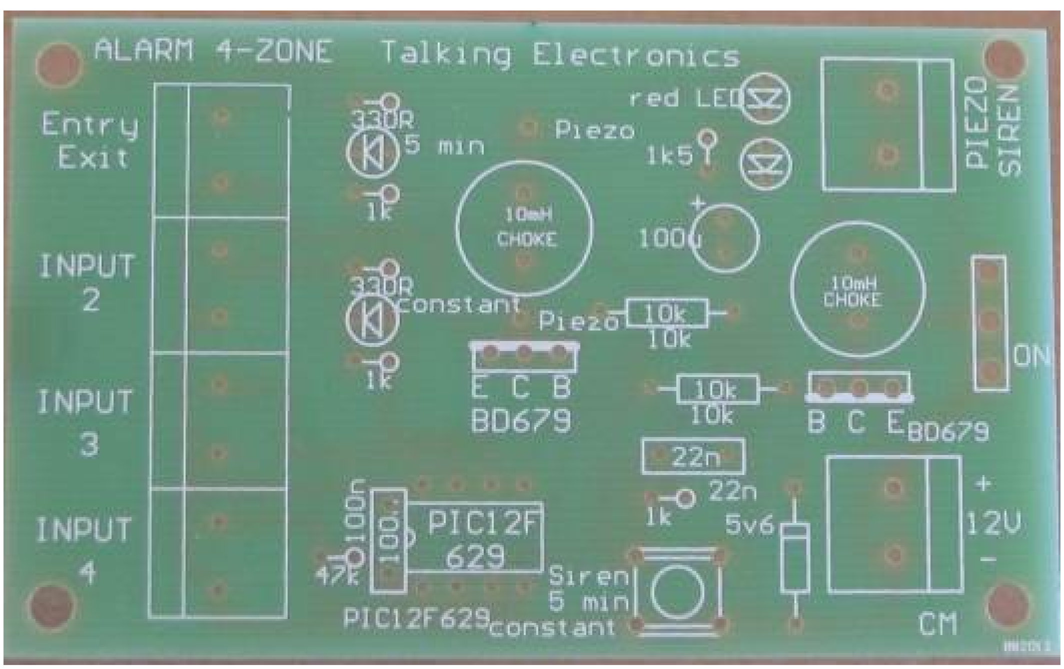
HOW THE CIRCUIT WORKS

Any of the inputs can be used for the Entry/Exit.
It is connected to the door you will use to enter or exit the property. The alarm gives you 45 seconds to exit.
When you enter the property, the buzzer turns on as soon as you open the door and beeps for 45 seconds to allow you to turn off the alarm.
If the alarm is not turned off, the main piezo siren produces a soft tone for 30 seconds and then a piercing wailing sound.





This allows you to turn off the alarm before the loud wailing is produced and is one of the best features of the alarm as the worry of false-triggering an alarm prevents many householders setting their alarm.
Any unused inputs must be connected with a link so the alarm can be set.
When the circuit is turned ON, you have 45 seconds to exit the premises.
The chip then flashes either the 5-min LED or the Constant LED to indicate if the siren will wail for 5 minutes or constantly. You can change the setting by pressing the button. The circuit then beeps for 45 seconds to give you time to exit the property. It then monitors all 4 inputs.



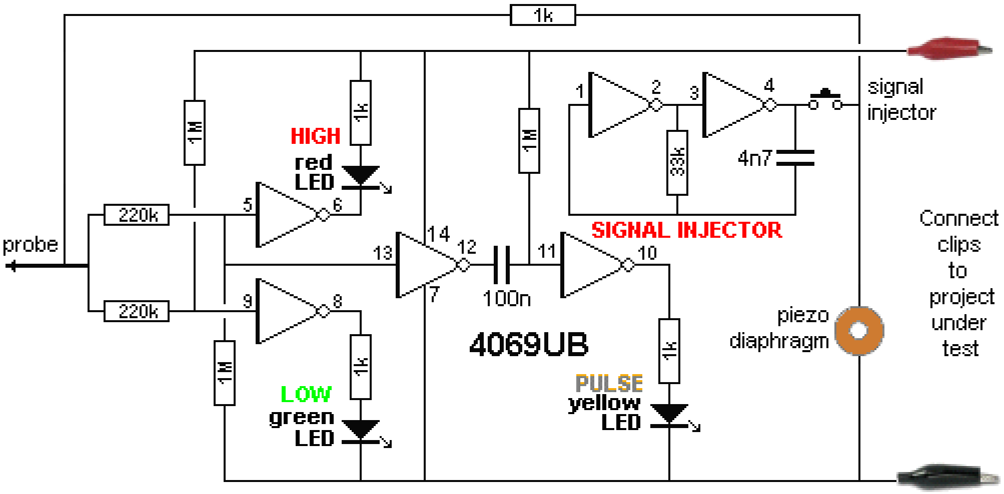
Alarm 4-Zone PCB

The main chip contains an internal oscillator to drive a piezo diaphragm and also a wailing oscillator for the Piezo Siren. The Piezo Siren is an 80dB piezo diaphragm driven by a BD679 Darlington transistor with a 10mH choke to produce a high voltage for the diaphragm.
The chip operates on 5v and the rest of the circuit uses 12v. A very simple voltage-dropper consisting of 2 LEDs and 1k5 drops the 12v to 5v.

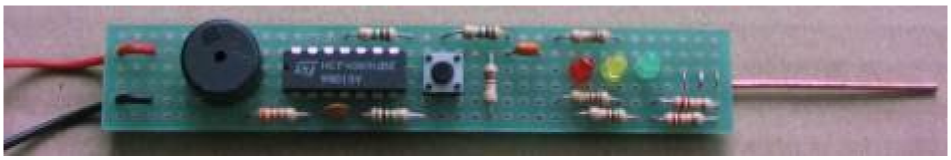
LOGIC PROBE

Kits are available for this project from Talking Electronics for $8.00 plus postage.

A **LOGIC PROBE** is a very handy piece of equipment to have when testing a project. This project provides: High, Low, Pulse, detects a Tone and has a Signal Injection feature. You can build it in an evening on a piece of Matrix Board.

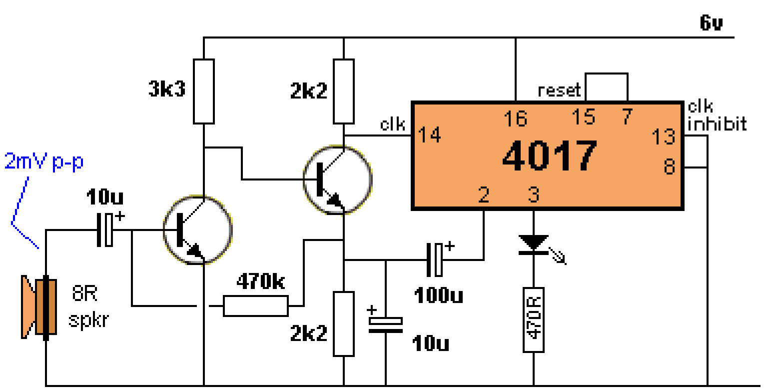


LOGIC PROBE with SIGNAL INJECTOR



CLAP SWITCH "ON-OFF"

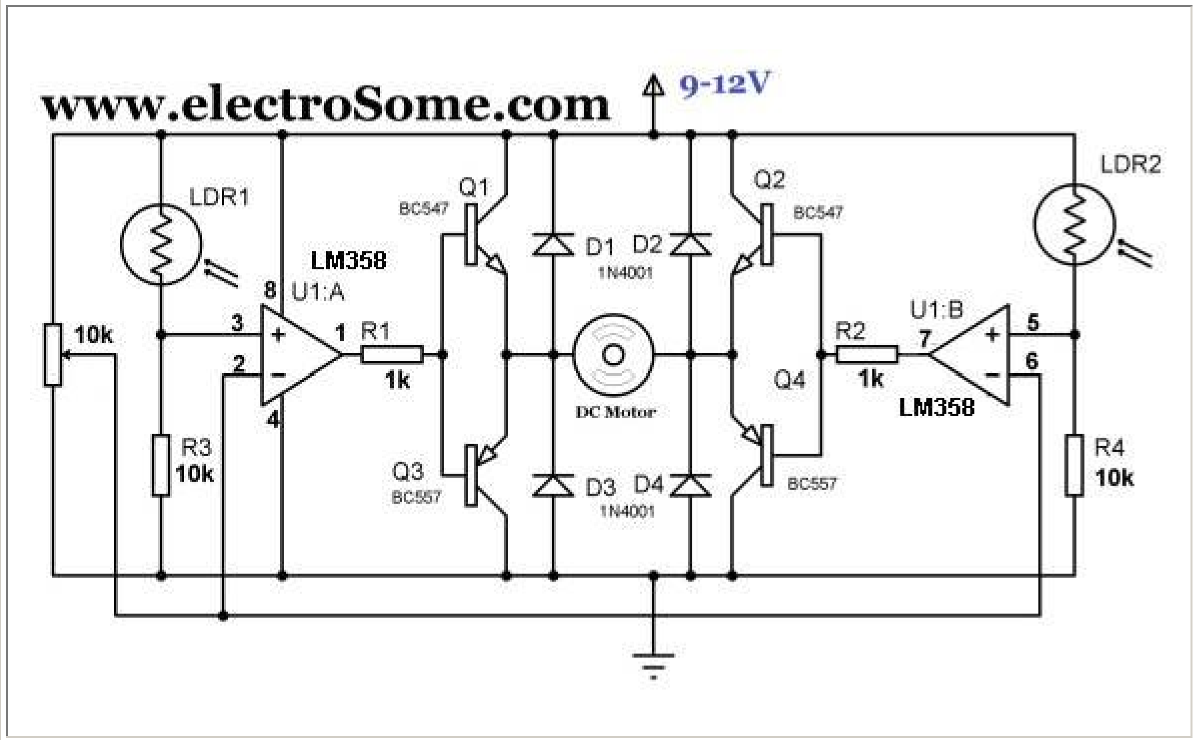
This circuit turns the LED ON with a clap or short whistle. And a further clap turns it OFF. It uses a speaker as a microphone and the fourth output of the 4017 is used to reset the chip. The 100u on pin 2 upsets the amplifier and prevents it clocking the chip, until the electro either charges or discharges. A buffer transistor can replace the LED to operate a relay. It only requires 2mV signal to activate the circuit.



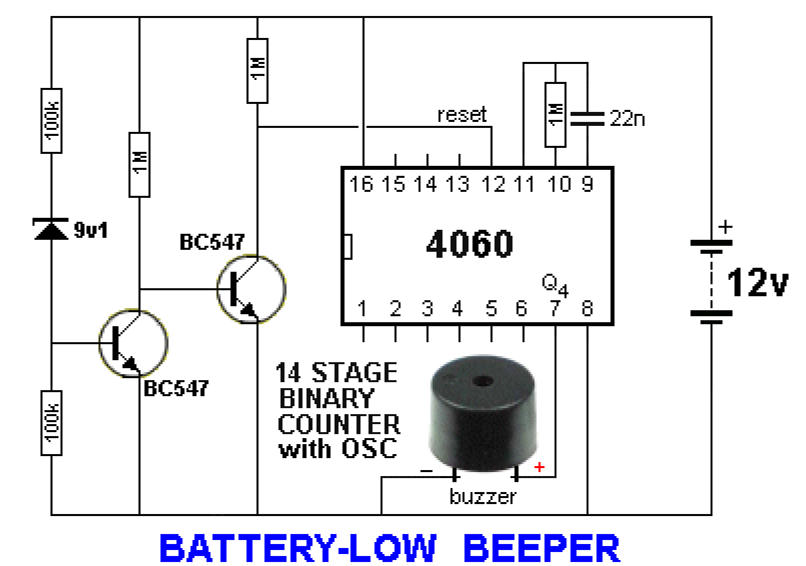
SOLAR TRACKER

This circuit can be used to track the movement of the sun. The Motor should be connected to the panel so it rotates the panel in the direction of movement of the sun.

See: http://www.electrosome.com/solar-tracker-system-using-lm358/

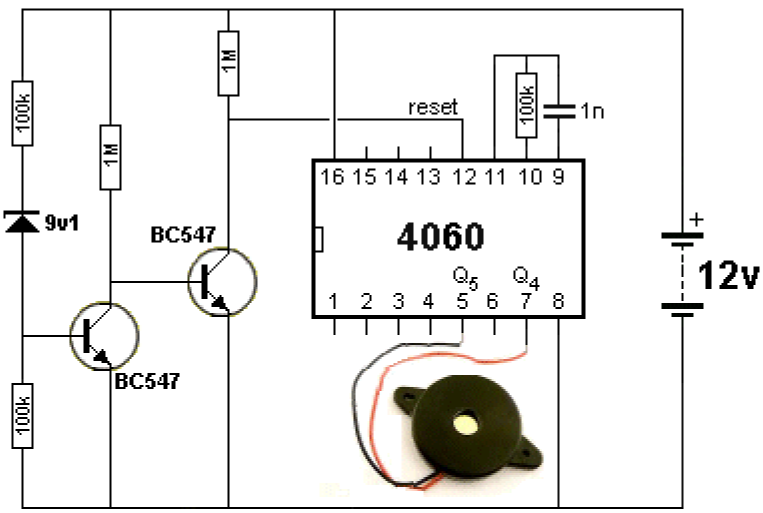


BATTERY-LOW BEEPER



This circuit will produce a beep-beep-beep from the piezo buzzer when the battery voltage falls to about 10v.
This is very handy when you have a battery powering a piece of equipment and you don't know its state of charge.
When the voltage is above 10v, the zener diode conducts and turns ON the first transistor. The voltage between the collector and emitter of this transistor is less than 0.3v and the voltage on the base of the second transistor is 0.3v. Thus the second transistor is not turned ON and it is effectively removed from the circuit. This means the reset pin of the CD 4060 is connected to the positive rail via a 1M resistor. This puts a HIGH on the reset pin and turns the chip off and prevents the oscillator producing clock pulses.
The chip contains inverters between pins 9, 10 and 11 so that when components are connected to these pins, an oscillator is produced. The technical name for this oscillator is called a CLOCK.
When pin 12 is taken HIGH it inhibits the oscillator (prevents the clock pulses passing to the divider stages).
When the battery voltage falls below 10v, the first transistor is turned OFF and the second transistor is turned ON. This takes the reset line to the 0v rail and the chip allows the clock pulses from the oscillator to pass to a set of flip flops arranged to divide the signal.

Pin 7 divides the signal by 16 to produce a beep-beep-beep from the electro-mechanical buzzer. The buzzer normally produces a constant tone but output pin 7 goes HIGH/LOW at about one cycle per second and this turns the buzzer ON and OFF to produce a clearer alert signal.
The circuit takes 30uA when "sitting around" and less than 1mA when producing a beep.
If you do not have an electro-mechanical buzzer, a piezo diaphragm can be used. The output volume will not be as loud. The oscillator components will need to be changed to produce a higher clock frequency. This frequency will be divided-down and detected at one or two of the outputs. You can try all the outputs to see what result is the best.

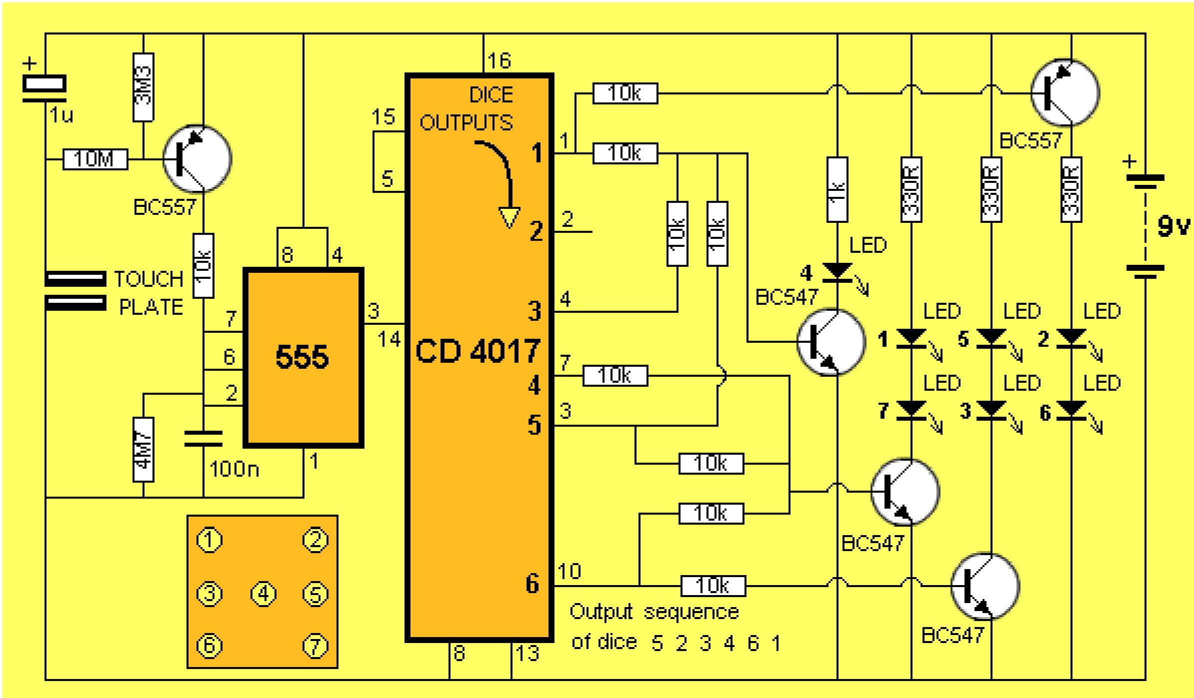


BATTERY-LOW BEEPER

If you do not have a 9v1 zener, it can be made from 5v6 zener and 3v6 zener or a 5v6 and a white LED or two red LEDs.
It can also be made from three white LEDs and a red LED.
You can use a zener, LEDs and a signal diode to adjust the voltage to any desired value.
When a very small current flows though a zener, LED or diode, the characteristic voltage that develops across it is LESS than when its rated current flows. However this lower voltage can be used to produce a "trigger-point." The only way to determine this voltage is to add the component to the circuit.
The first transistor reacts at this trigger-point and the second transistor simply inverts the voltage on the collector.
The second transistor is not classified as an amplifier but an INVERTER.
To see more on this project, visit: http://electronicsmaker.info

LED DICE

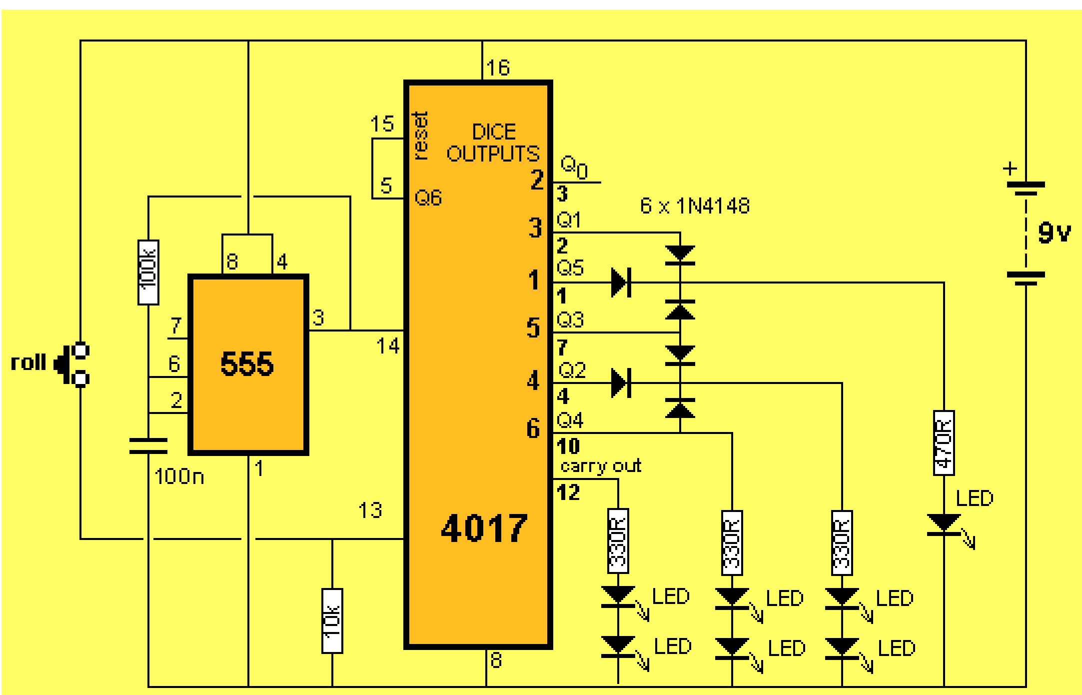
This circuit produces a realistic effect of the "pips" on the face of a dice. The circuit has "slow-down" to give the effect of the dice "rolling."
See the full project: **LED DICE**



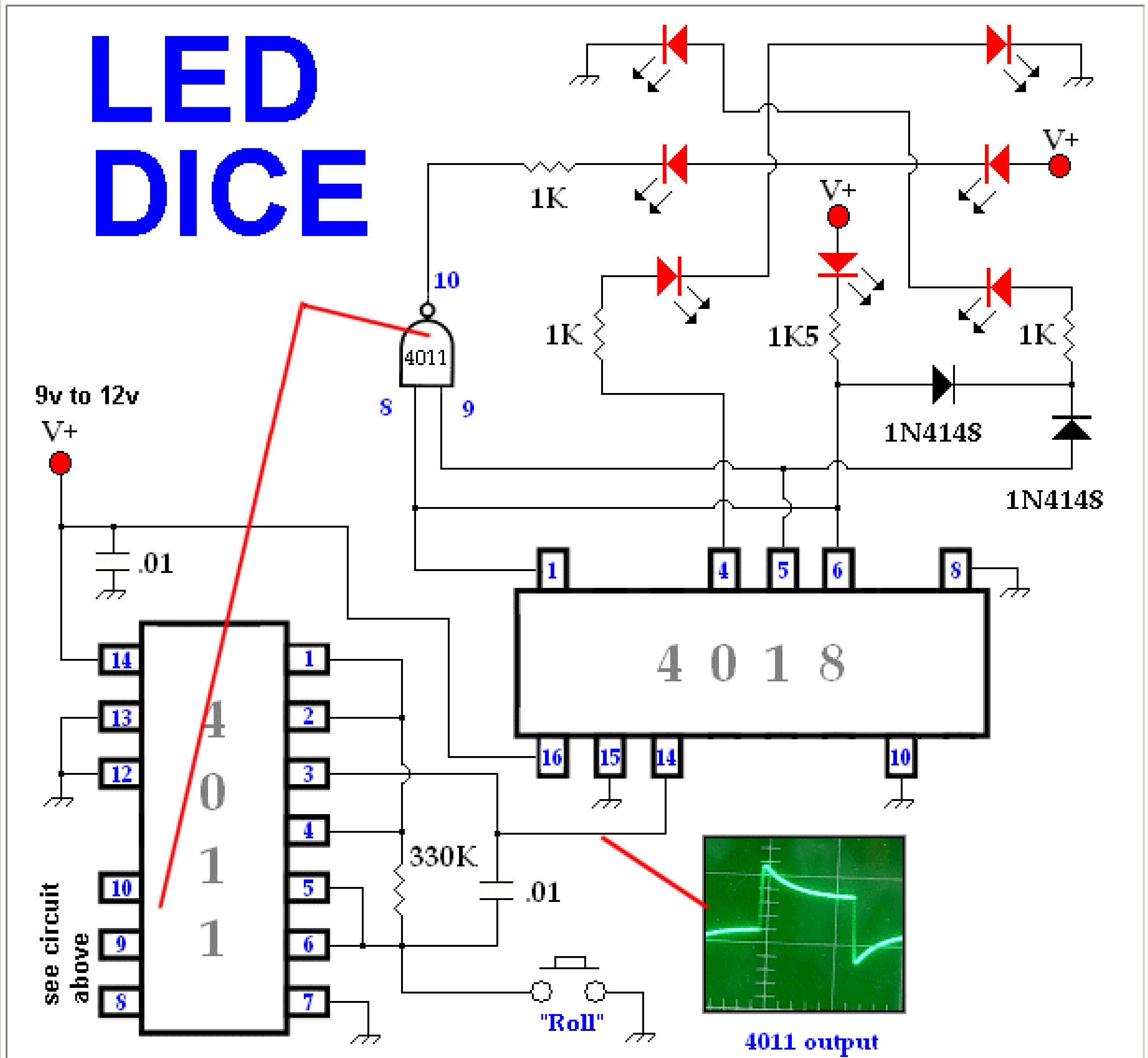
A SIMPLER CIRCUIT:

The circuit above can be simplified and output Pin 12 can be used to illuminate two of the LEDs as this line is HIGH for the times when Q0, Q1, Q2, Q3, and Q4 are HIGH and goes LOW when Q5 - Q9 is HIGH.

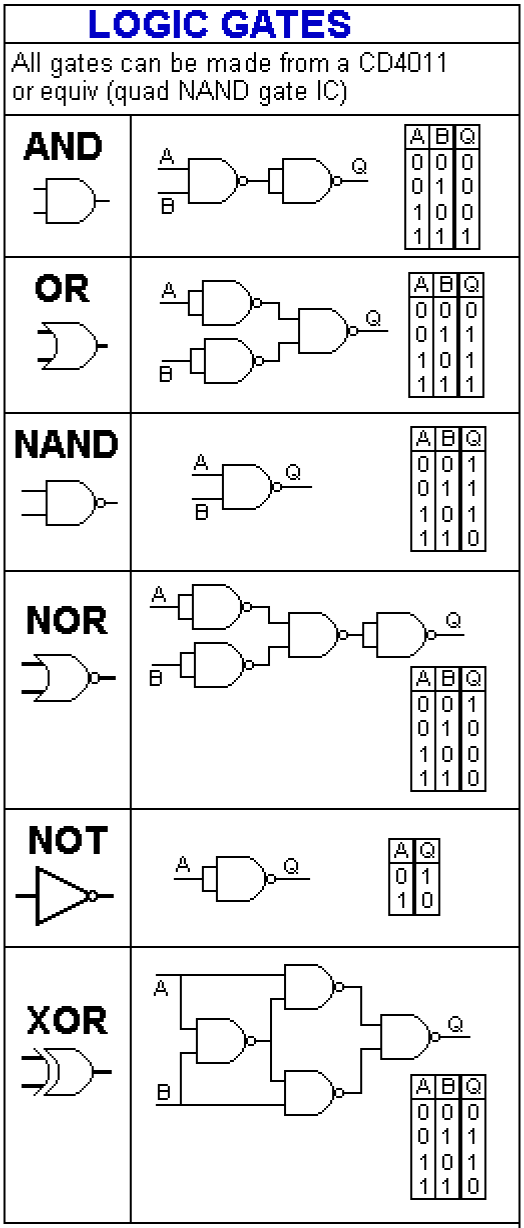
This means the 4017 starts with Q0 HIGH. But Q0 is not an output. This means that when Q0 is HIGH, "carry out" is HIGH and "2" will be displayed. The next clock cycle will produce "3" on the display when Q1 is HIGH, then "4" when Q2 is HIGH, "5" when Q3 is HIGH and "6" when Q4 is HIGH. When Q5 goes HIGH, it illuminates "1" on the display because "carry out" goes LOW.



LED DICE - minimum components



LED DICE - using CD4018 5-bit Counter



LOGIC GATES
It's very handy to remember that all the logic gates can be made from a Quad NAND gate such as CD4011.

Circuit Symbols

The list below covers almost every symbol you will find on an electronic circuit diagram. It allows you to identify a symbol and also draw circuits. It is a handy reference and has some symbols that have never had a symbol before, such as a Flashing LED and electroluminescence panel.
Once you have identified a symbol on a diagram you will need to refer to specification sheets to identify each lead on the actual component.
The symbol does not identify the actual pins on the device. It only shows the component in the circuit and how it is wired to the other components, such as input line, output, drive lines etc. You cannot relate the shape or size of the symbol with the component you have in your hand or on the circuit-board.
Sometimes a component is drawn with each pin in the same place as on the chip etc. But this is rarely the case.
Most often there is no relationship between the position of the lines on the circuit and the pins on the component.

That’s what makes reading a circuit so complex.

This is very important to remember with transistors, voltage regulators, chips and so many other components as the position of the pins on the symbol are not in the same places as the pins or leads on the component and sometimes the pins have different functions according to the manufacturer. Sometimes the pin numbering is different according to the component, such as positive and negative regulators.

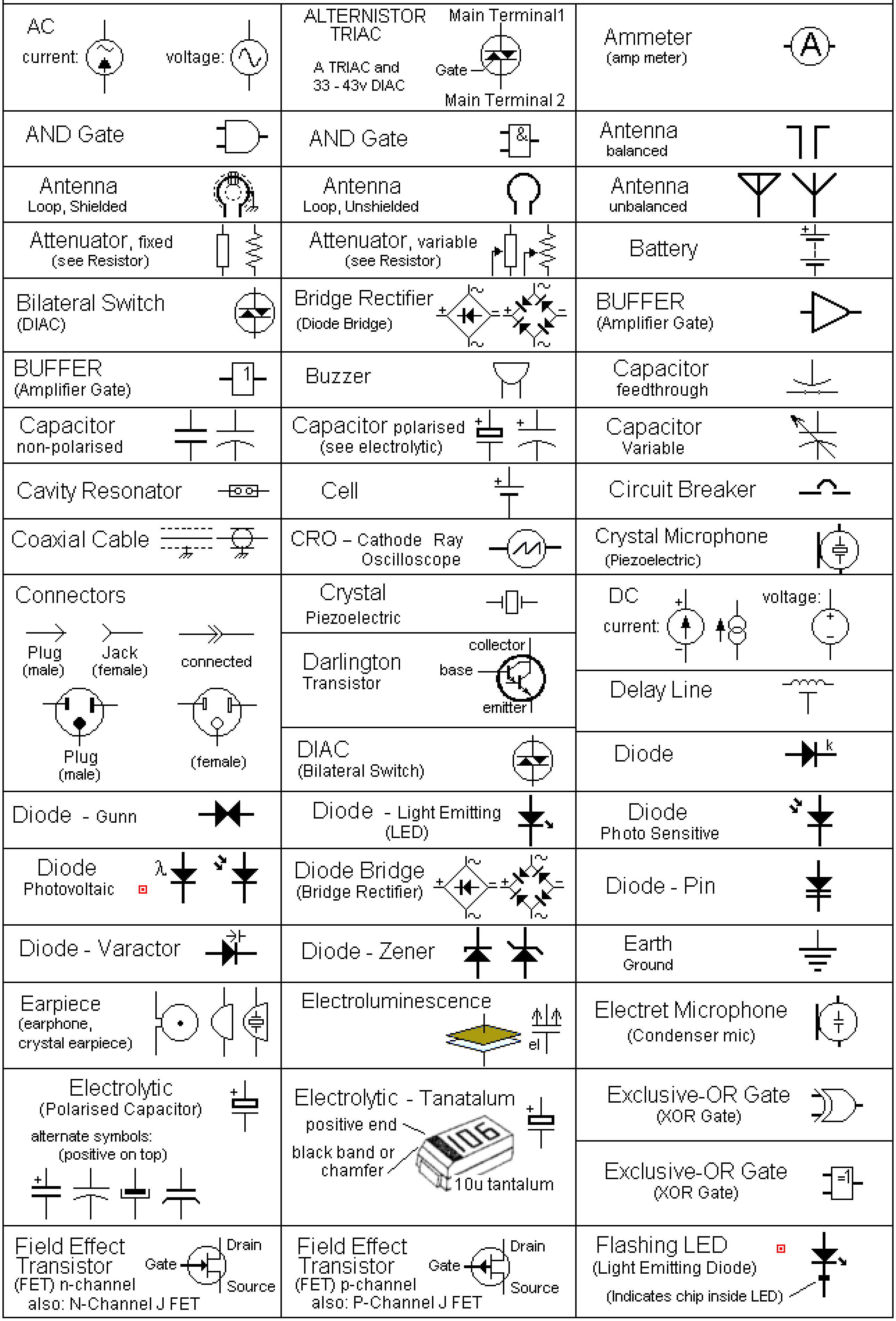
You must to refer to the manufacturer's specification sheet to identify each pin, to be sure you have identified them correctly.

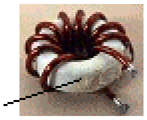
Colin Mitchell

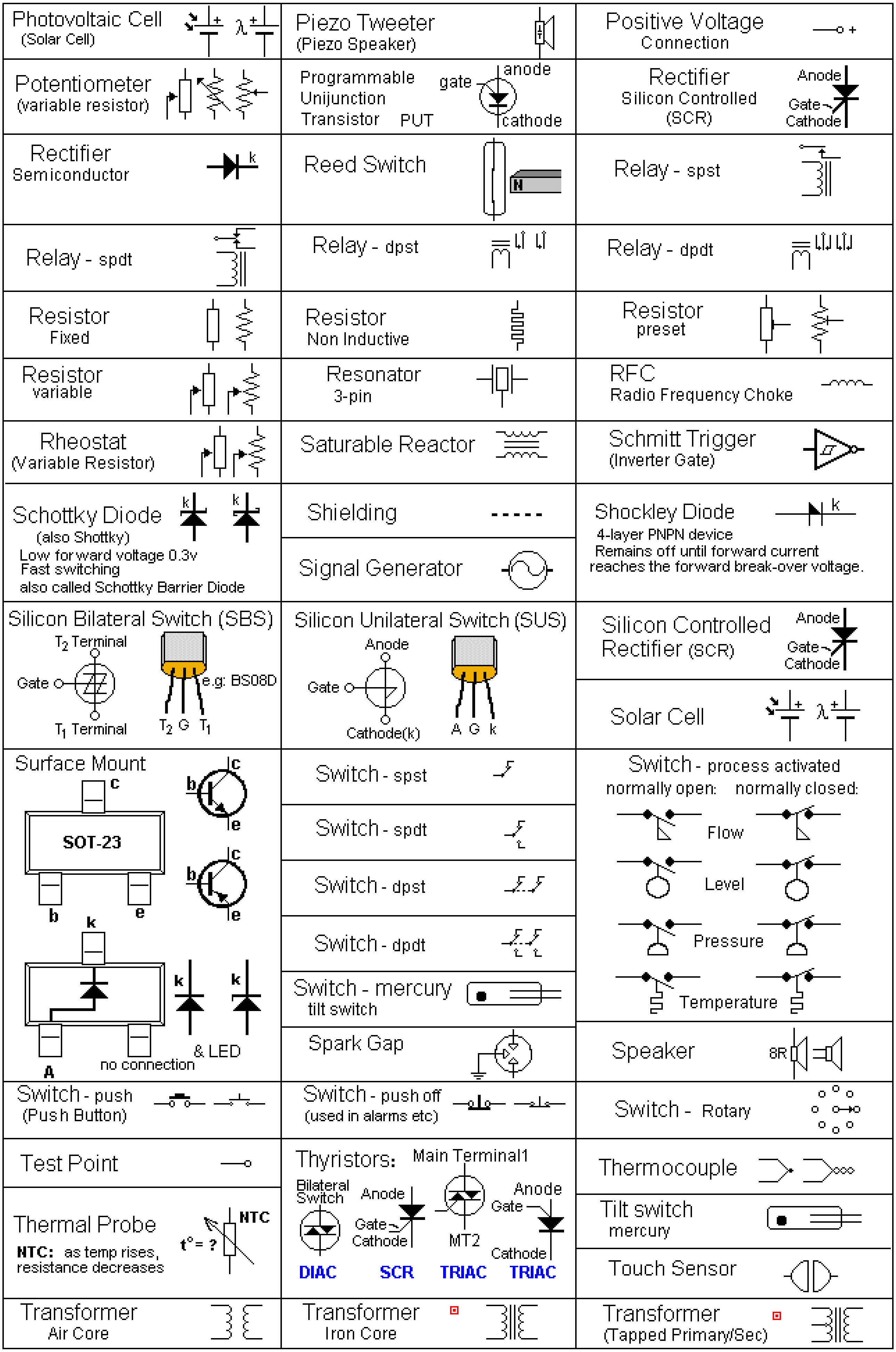
CIRCUIT SYMBOLS

Some additional symbols have been added to the following list. See **Circuit Symbols** on the index of Talking Electronics.com for the latest additions.

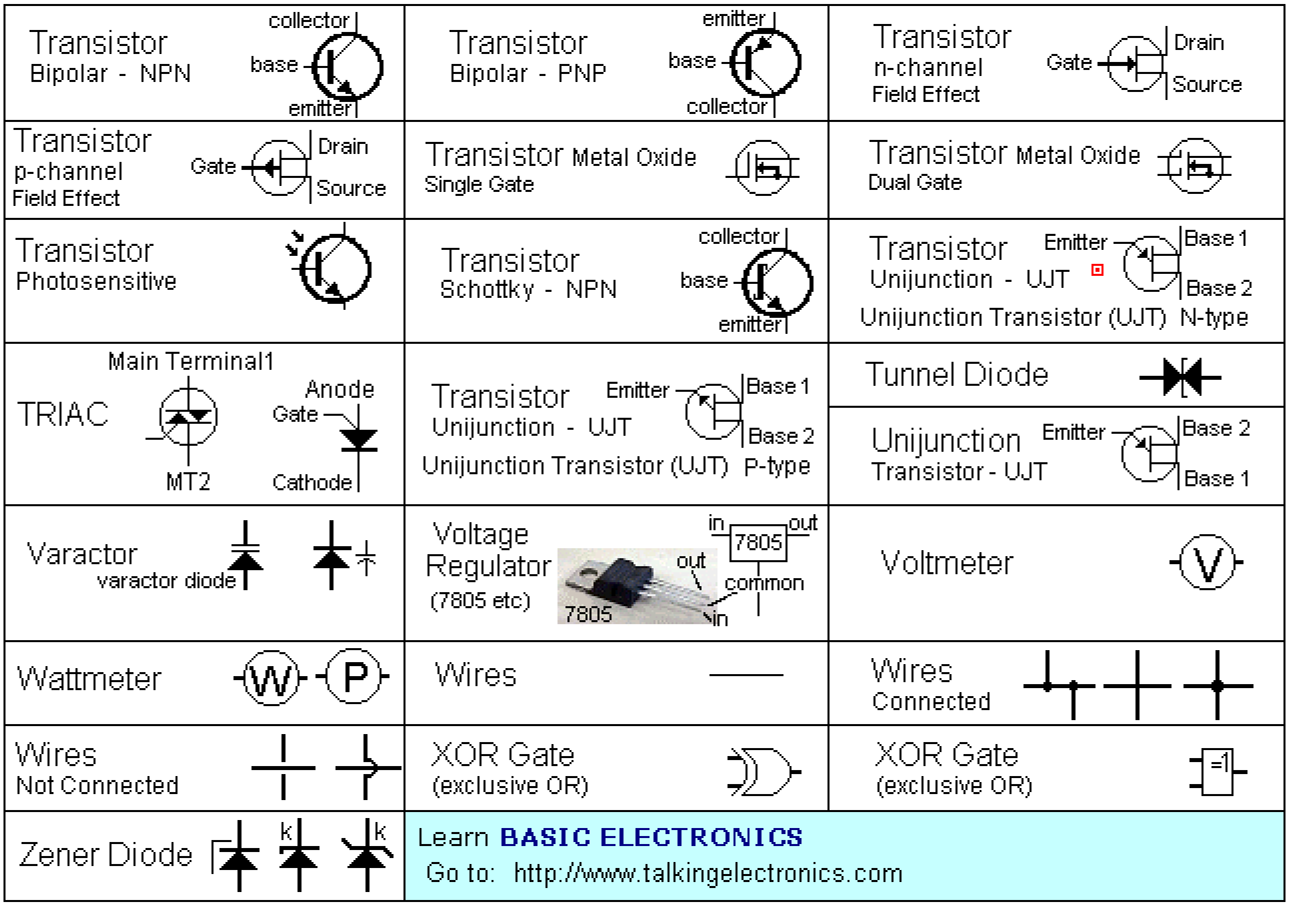
CIRCUIT SYMBOLS by TALKING ELECTRONICS



Ferrite Bead	Fuse	Galvanometer G
Globe	Ground Chassis	Ground Earth
Heater (immersion heater) (cooker etc)	IC Integrated Circuit power ground	Inductor Air Core
Headphone		Inductor Iron Core or ferrite core 
Inductor Tapped	Inductor Variable	Integrated Circuit 
Inverter (NOT Gate)	INVERTER (NOT Gate) 1	
Jack Co-axial	Jack Phone (Phone Jack)	Jack Phone (Switched)
Jack Phone (3 conductor)	Key Telegraph (Morse Key)	Lamp Incandescent
Lamp - Neon	LASCR (Light Activated Silicon Controlled Rectifier)	LDR (Light Dependent Resistor)
LASER diode laser diode photo diode	Light Emitting Diode (LED) 	Light Emitting Diode (LED - flashing) (Indicates chip inside LED)
Mercury Switch	Micro-amp meter (micro-ammeter) µA	Microphone (see Electret Mic) 
Microphone (Crystal - piezoelectric)	Milliamp meter (milli-ammeter) mA	Motor MOT
NAND Gate	NAND Gate &	Nitinol wire "Muscle wire"
Negative Voltage Connection	NOR Gate	NOR Gate
NOT Gate Inverter	NOT Gate Inverter 1	Ohm meter Ω
Operational Amplifier (Op Amp)	Optocoupler (Transistor output)	Opto Coupler (Opto-isolator) a c k e Photo-transistor output
Optocoupler (Darlington output)	Opto Coupler (Opto-isolator) a c k e TRIAC output	OR Gate
OR Gate	Oscilloscope see CRO	Outlet (Power Outlet)
Piezo Diaphragm	Photo Cell (photo sensitive resistor)	Photo Diode
Photo Darlington Transistor	Photo FET Gate Drain (Field Effect Transistor) Source	Photo Transistor

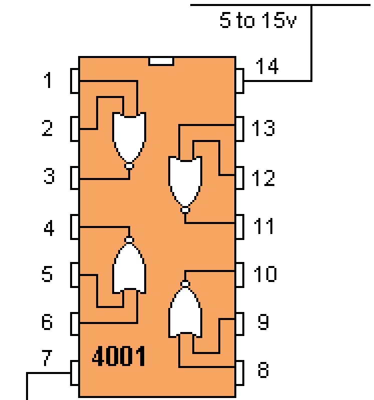


Photovoltaic Cell
(Solar Cell)
Piezo Tweeter
(Piezo Speaker)
Positive Voltage
Connection
Potentiometer
(variable resistor)
Programmable
Unijunction
Transistor PUT
gate
anode
cathode
Rectifier
Silicon Controlled
(SCR)
Anode
Gate
Cathode
Rectifier
Semiconductor
k
Reed Switch
N
Relay - spst
Relay - spdt
Relay - dpst
Relay - dpdt
Resistor
Fixed
Resistor
Non Inductive
Resistor
preset
Resistor
variable
Resonator
3-pin
RFC
Radio Frequency Choke
Rheostat
(Variable Resistor)
Saturable Reactor
Schmitt Trigger
(Inverter Gate)
Schottky Diode
(also Shottky)
Low for ward voltage 0.3v
Fast switching
also called Schottky Barrier Diode
k
k
Shielding
Signal Generator
Shockley Diode
k
4-layer PNPN device
Remains off until forward current
reaches the forward break-over voltage.
Silicon Bilateral Switch (SBS)
T2 Terminal
Gate
T1 Terminal
e.g: BS08D
T2 G T1
Silicon Unilateral Switch (SUS)
Anode
Gate
Cathode(k)
A G k
Silicon Controlled
Rectifier (SCR)
Anode
Gate
Cathode
Solar Cell
Surface Mount
c
SOT-23
b
e
b
c
e
b
c
e
k
k
k
& LED
A
no connection
Switch - spst
Switch - spdt
Switch - dpst
Switch - dpdt
Switch - mercury
tilt switch
Spark Gap
Switch - process activated
normally open: normally closed:
Flow
Level
Pressure
Temperature
Speaker
8R
Switch - push
(Push Button)
Switch - push off
(used in alarms etc)
Switch - Rotary
Test Point
Thyristors:
Main Terminal1
Bilateral
Switch
Anode
Gate
Cathode
MT2
Anode
Gate
Cathode
DIAC
SCR
TRIAC
TRIAC
Thermocouple
Thermal Probe
NTC
t° = ?
NTC: as temp rises,
resistance decreases
Tilt switch
mercury
Touch Sensor
Transformer
Air Core
Transformer
Iron Core
Transformer
(Tapped Primary/Sec)

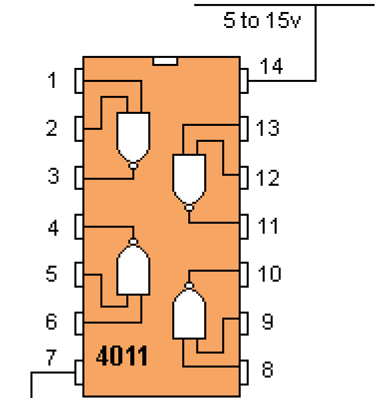


IC PINOUTS

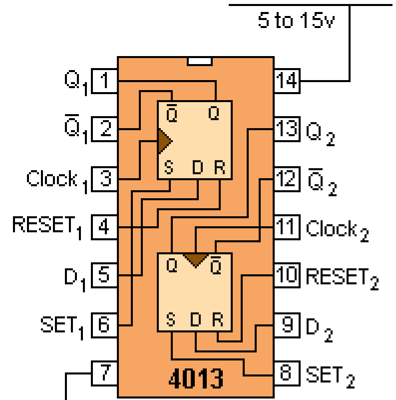
The following list covers just a few of the IC's on the market and these are the "simple" or "basic" or "digital" or "op-amp" IC's suitable for experimenting.
When designing a circuit around an IC, you have to remember two things:
1. Is the IC still available? and
2. Can the circuit be designed around a microcontroller?
Sometimes a circuit using say 3 or 4 IC's can be re-designed around an 8-pin or 16-pin microcontroller and the program can be be kept from prying eyes due to a feature called "code protection." A microcontroller project is more up-to-date, can be cheaper and can be re-programmed to alter the features.
This will be covered in the next eBook. It is worth remembering - as it is the way of the future.



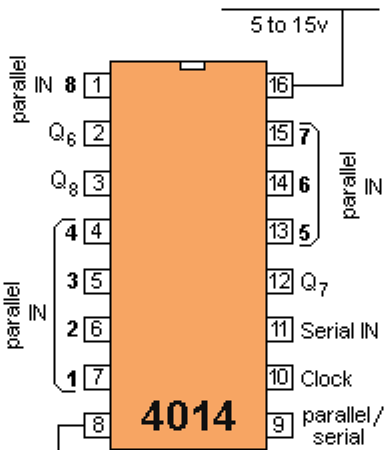
QUAD 2-INPUT
NOR gate



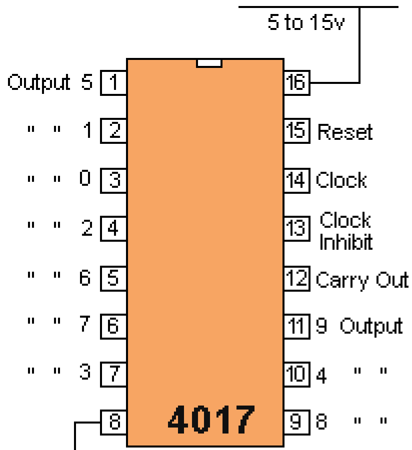
QUAD 2-INPUT
NAND gate



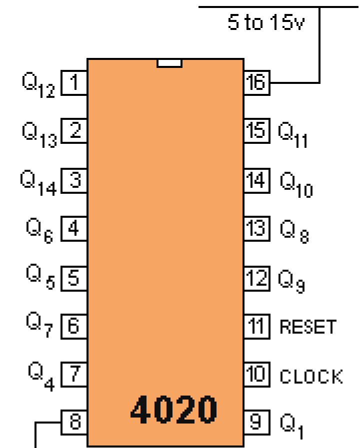
DUAL D FLIP FLOP



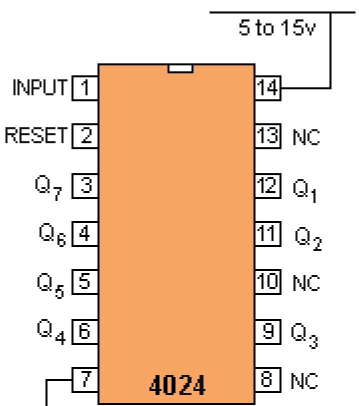
8-BIT SHIFT
REGISTER



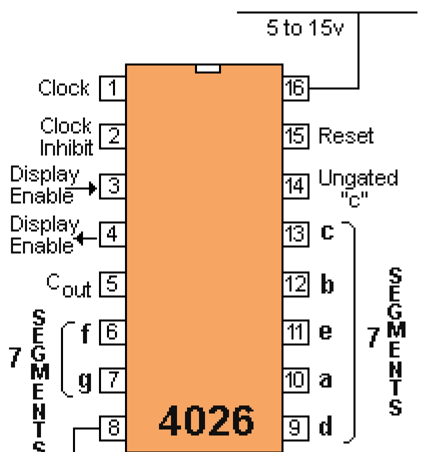
DECADE COUNTER
DIVIDER



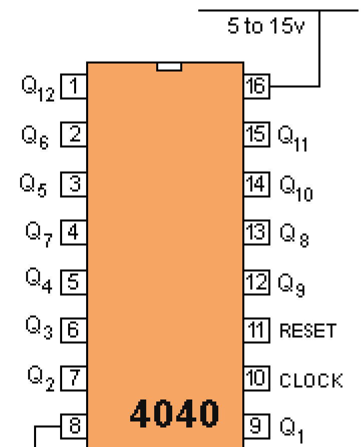
14 STAGE BINARY
COUNTER



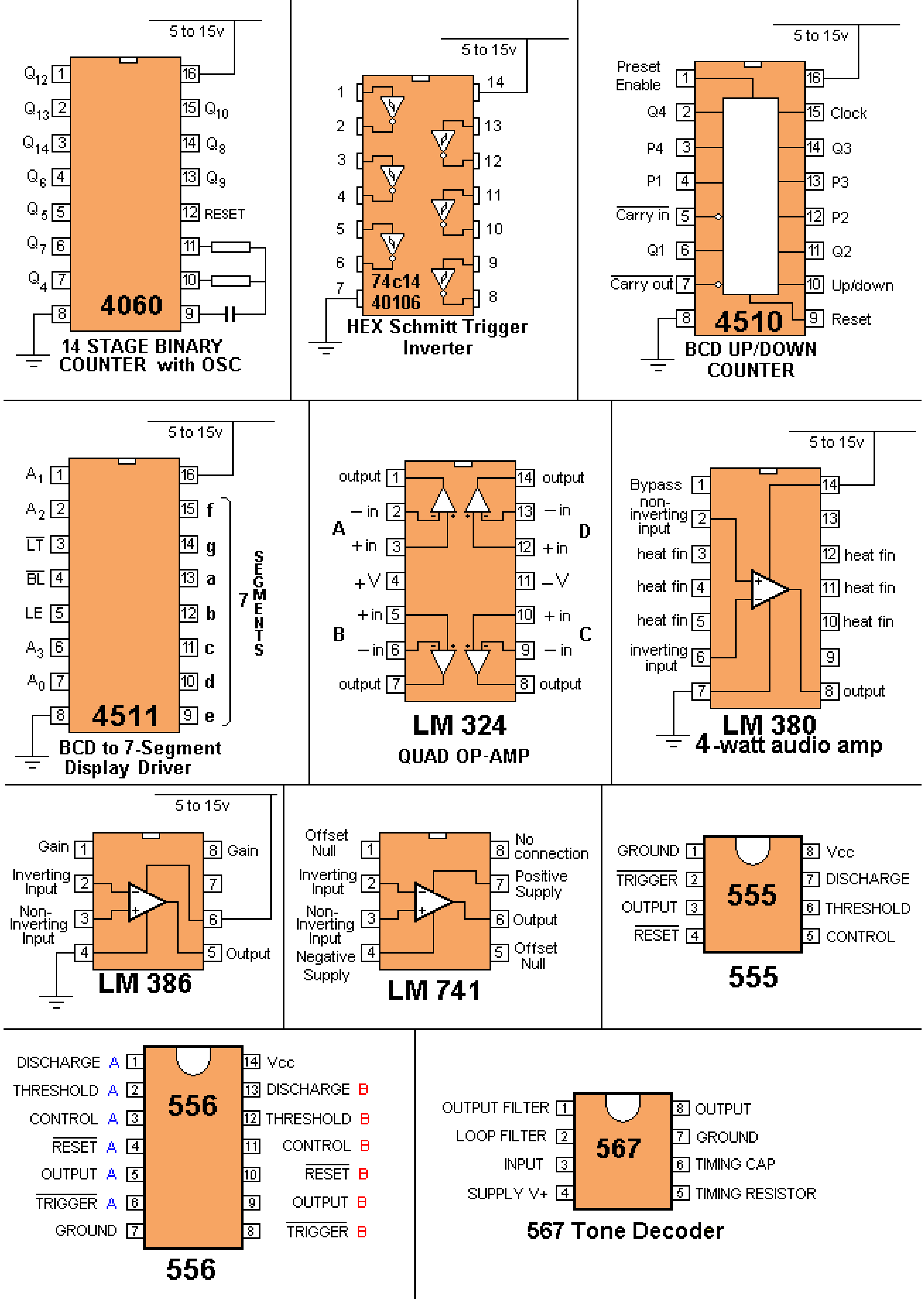
7-STAGE BINARY
COUNTER



7-Segment Display
Driver

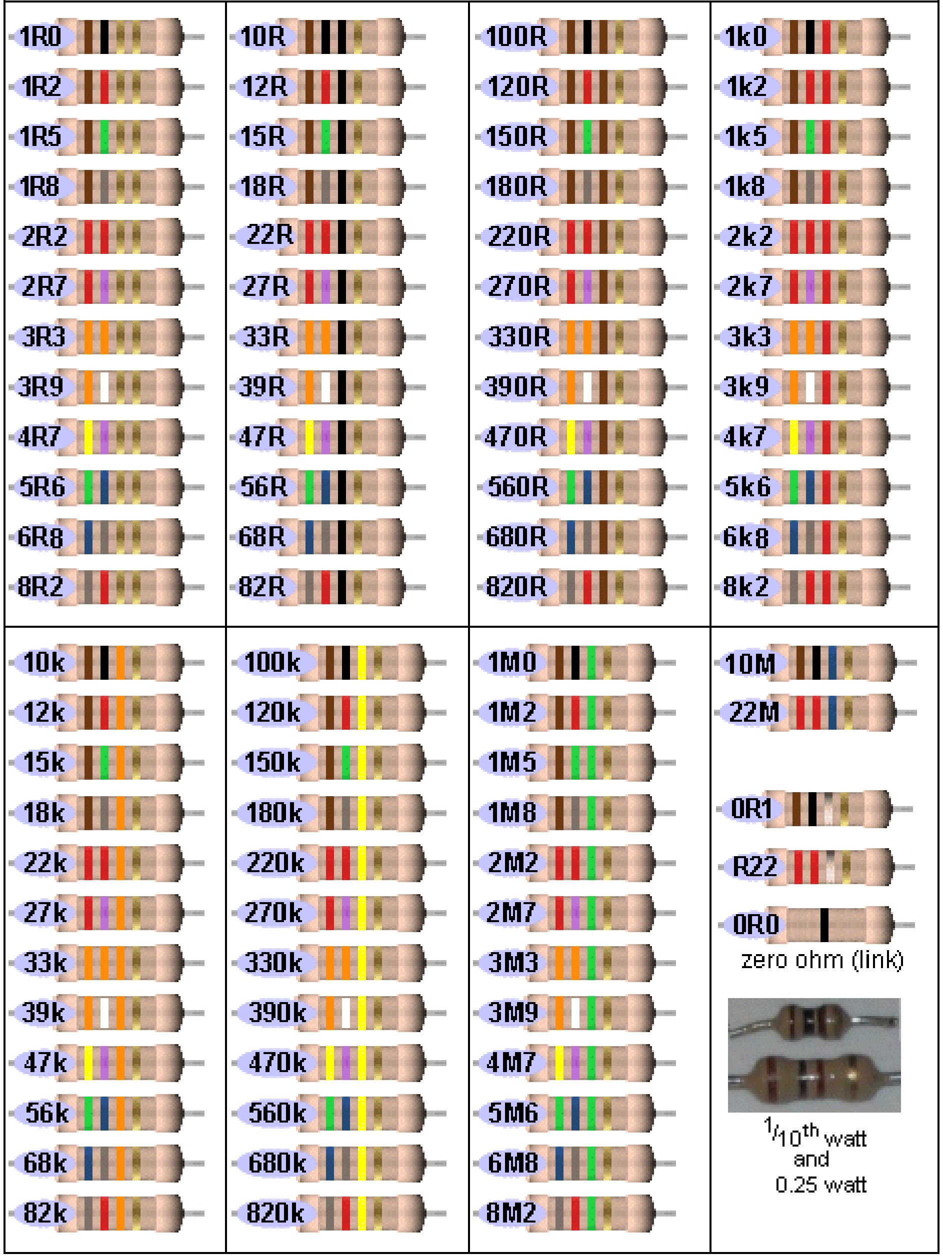


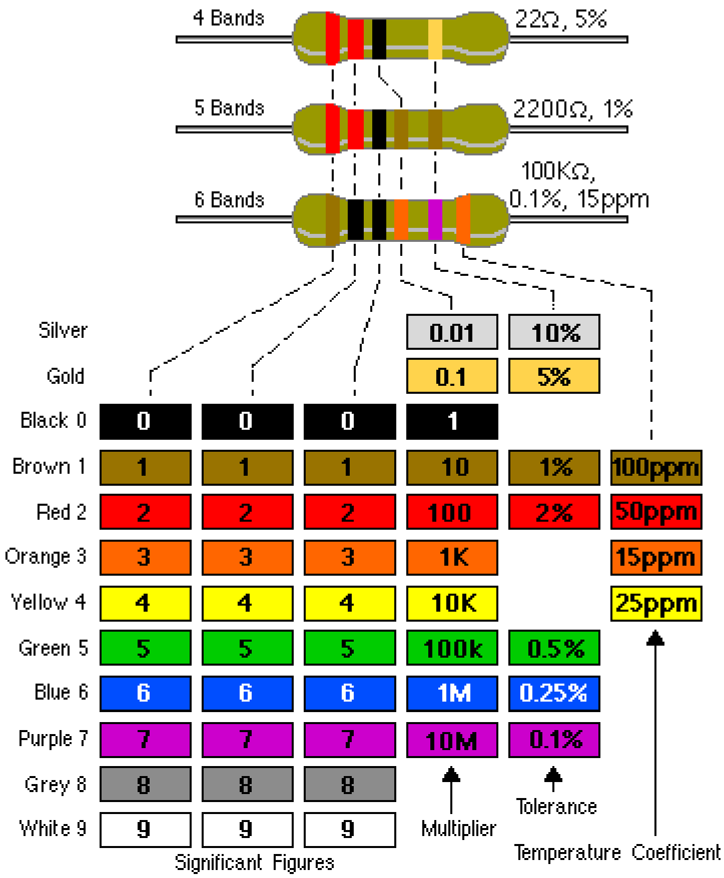
12 STAGE BINARY
COUNTER



All the resistor colours:

This is called the "normal" or "3 colour-band" (5%) range. If you want the 4 colour-band (1%) series, refer to Talking Electronics website and click: **Resistors 1%** on the left index. Or you can use the table below.


1R0
1R2
1R5
1R8
2R2
2R7
3R3
3R9
4R7
5R6
6R8
8R2
10R
12R
15R
18R
22R
27R
33R
39R
47R
56R
68R
82R
100R
120R
150R
180R
220R
270R
330R
390R
470R
560R
680R
820R
1k0
1k2
1k5
1k8
2k2
2k7
3k3
3k9
4k7
5k6
6k8
8k2
10k
12k
15k
18k
22k
27k
33k
39k
47k
56k
68k
82k
100k
120k
150k
180k
220k
270k
330k
390k
470k
560k
680k
820k
1M0
1M2
1M5
1M8
2M2
2M7
3M3
3M9
4M7
5M6
6M8
8M2
10M
22M
0R1
R22
0R0
zero ohm (link)
1/10th watt
and
0.25 watt



Resistor Color Code System

MAKE ANY RESISTOR VALUE:

If you don't have the exact resistor value for a project, don't worry. Most circuits will work with a value slightly higher or lower.
But if you want a particular value and it is not available, here is a chart.
Use 2 resistors in series or parallel as shown:

Required Value	R1	Series/ Parallel	R2	Actual value:
10	4R7	S	4R7	9R4
12	10	S	2R2	12R2
15	22	P	47	14R9
18	22	P	100	18R
22	10	S	12	22
27	22	S	4R7	26R7
33	22	S	10	32R
39	220	P	47	38R7
47	22	S	27	49
56	47	S	10	57
68	33	P	33	66
82	27	P	56	83

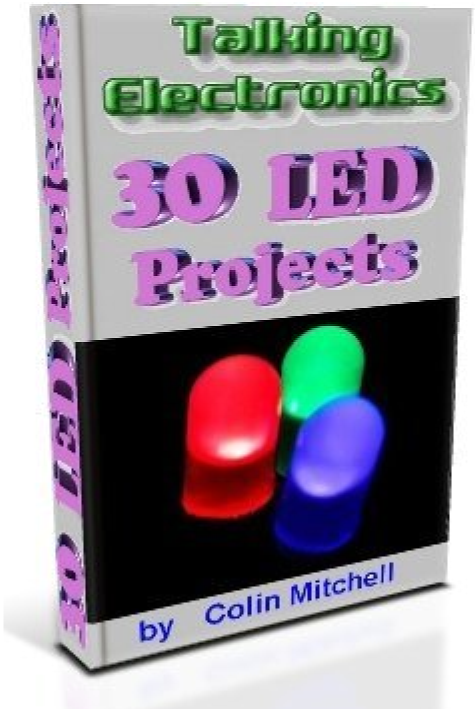
There are other ways to combine 2 resistors in parallel or series to get a particular value. The examples above are just one way.
4R7 = 4.7 ohms

MAKE ANY CAPACITOR VALUE:

If you don't have the exact capacitor value for a project, don't worry. Most circuits will work with a value slightly higher or lower.
But if you want a particular value and it is not available, here is a chart.
Use 2 capacitors in series or parallel as shown:

Required Value	C1	Series/ Parallel	C2	Actual value:
10	4.7	P	4.7	9.4
12	10	P	2.2	12.2
15	22	S	47	14.9
18	22	S	100	18
22	10	P	12	22
27	22	P	4.7	26.7
33	22	P	10	32
39	220	S	47	38.7
47	22	P	27	49
56	47	P	10	57
68	33	S	33	66
82	27	S	56	83

The value "10" in the chart above can be 10p, 10n or 10u. The chart works for all decades (values).



Save 30 LED Projects as**: [.doc] (957KB) or [.pdf] (770KB)** **(21-5-2011)**

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100 IC Circuits

For a list of every electronic symbol, see: Circuit Symbols.

For more articles and projects for the hobbyist: **see TALKING ELECTRONICS WEBSITE**

email Colin Mitchell: talking@tpg.com.au

CONTENTS

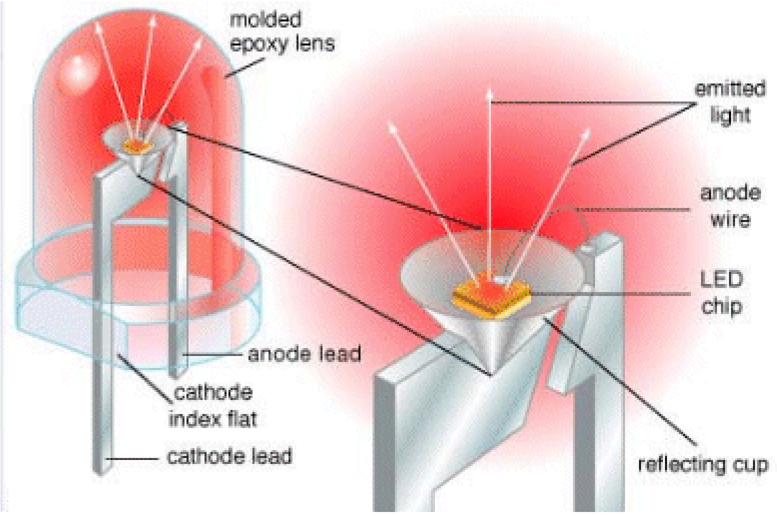
to Index

INTRODUCTION

This e-book covers the Light Emitting Diode.

The LED (Light Emitting Diode) is the modern-day equivalent to the light-globe.
It has changed from a dimly-glowing indicator to one that is too-bright to look at.
However it is entirely different to a "globe."
A globe is an electrical device consisting of a glowing wire while a LED is an electronic device.
A LED is more efficient, produces less heat and must be "driven" correctly to prevent it being damaged.
This eBook shows you how to connect a LED to a circuit plus a number of projects using LEDs.
It's simple to use a LED - once you know how.

INSIDE A LED:



Color	Material	Bandgap	V_γ
Blue	SiC	2.64 eV	3.2–4.9
Green	GaP	2.19 eV	2.2–2.5
Yellow	$GaP_{85}As_{15}$	2.11 eV	2.1–2.5
Orange	$GaP_{65}As_{35}$	2.03 eV	1.9–2.2
Red	GaP_4As_6	1.91 eV	1.7–2.7

Color of LED	Voltage Drop (Volt)
Red	1.63 ~ 2.03
Yellow	2.10 ~ 2.18
Orange	2.03 ~ 2.10
Blue	2.48 ~ 3.7
Green	1.9 ~ 4.0
Violet	2.76 ~ 4.0
UV	3.1 ~ 4.4
White	3.2 to 3.6

A "Natural" or "Characteristic" voltage develops across a LED when it is correctly connected in a circuit with a current-limiting resistor to allow a current of between 1mA and 20mA. This voltage is shown in the table above and we normally use the lower value for each colour. However the table shows the voltage varies quite a lot and this depends on the actual crystalline construction of the crystal and the way it is manufactured. You cannot change this and that's why you need to measure the voltage across the LED when building some of the circuits.

LED VOLTAGES

Here is another table showing LED Voltages. The voltage across a LED depends on the manufacturer, the intensity of the colour and the actual colour.

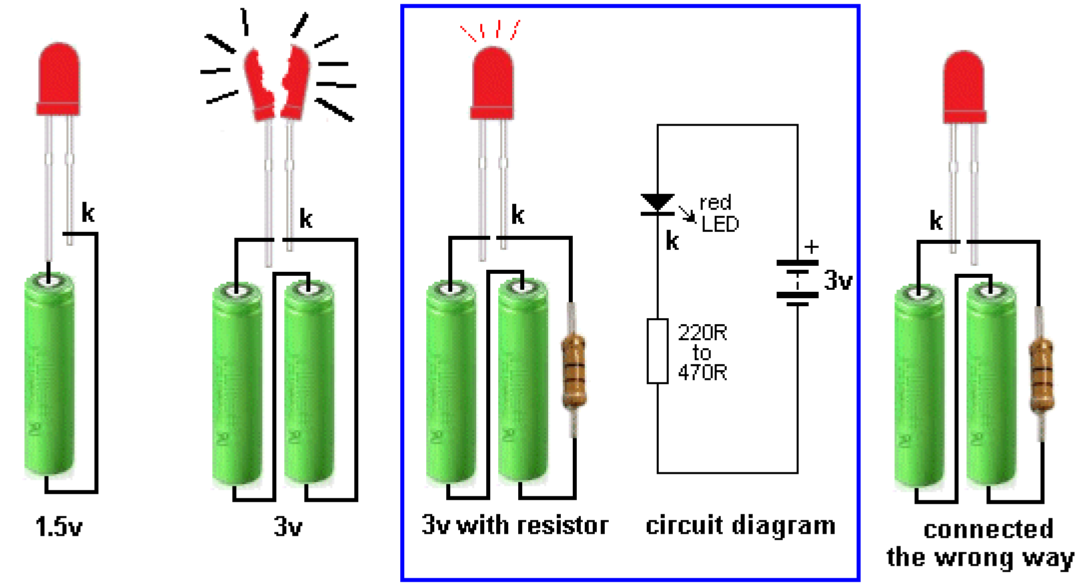
Color	Material	Wavelength (nm)	V-forward
Super Red	GaAIAs	660	1.8
Green	GaP	565	2
Red	GaAsP	635	2
Red	AlInGaP	636	2
Orange	AlInGaP	610	2
Yellow	AlInGaP	590	2
Amber	GaAsP	605	2.1
Red	GaP	700	2.1
Green	GaP	555	2.1
Green	AlInGaP	574	2.2
Blue	SiC	430	3.5
Green	InGaN	505	3.5
Blue	InGaN	470	3.5
White	InGaN		3.5
Green	InGaN	525	3.7
Green	InGaN	525	4
Blue	SiC	430	4.5

LED VOLTAGES depend on many factors. You must test the LED(s) you are using.

The voltage across some LEDs increases by 500mV (0.5v) when the current increases from about 10mA to 25-30mA and if you have 6 LEDs in series, this is an increase of 3v. If you are using a 12v supply, you will need to remove one LED to get the brightness you require.

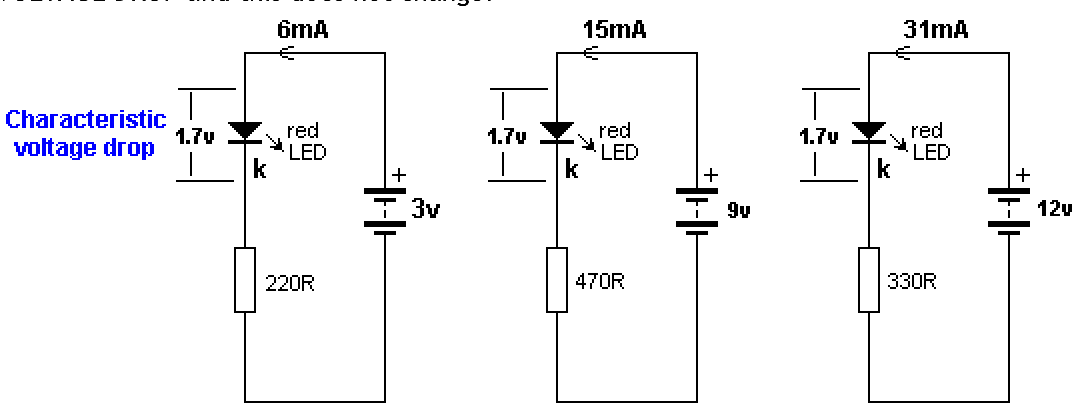
CONNECTING A LED

A LED must be connected around the correct way in a circuit and it must have a resistor to limit the current. The LED in the first diagram does not illuminate because a red LED requires 1.7v and the cell only supplies 1.5v. The LED in the second diagram is damaged because it requires 1.7v and the two cells supply 3v. A resistor is needed to limit the current to about 25mA and also the voltage to 1.7v, as shown in the third diagram. The fourth diagram is the circuit for layout #3 showing the symbol for the LED, resistor and battery and how the three are connected. The LED in the fifth diagram does not work because it is around the wrong way.

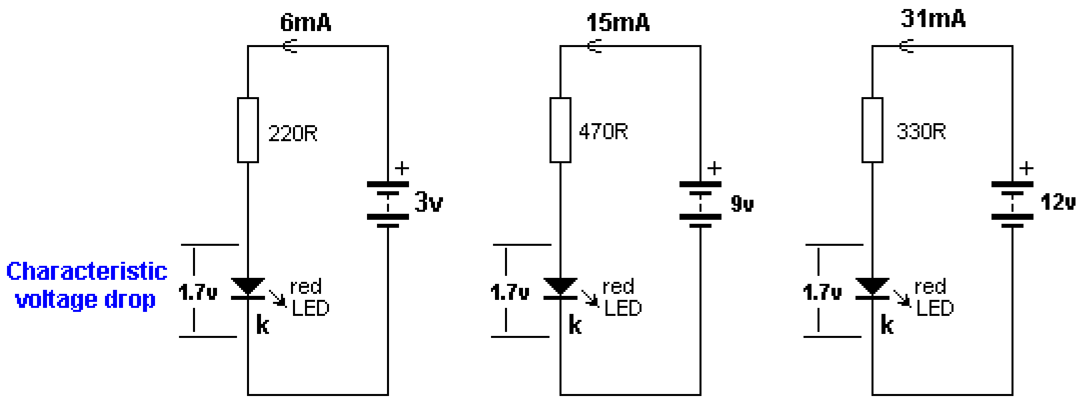


CHARACTERISTIC VOLTAGE DROP

When a LED is connected around the correct way in a circuit it develops a voltage across it called the CHARACTERISTIC VOLTAGE DROP.
A LED must be supplied with a voltage that is higher than its "CHARACTERISTIC VOLTAGE" via a resistor - called a VOLTAGE DROPPING RESISTOR or CURRENT LIMITING RESISTOR - so the LED will operate correctly and provide at least 10,000 to 50,000 hours of illumination.
A LED works like this: A LED and resistor are placed in series and connected to a voltage.
As the voltage rises from 0v, nothing happens until the voltage reaches about 1.7v. At this voltage a red LED just starts to glow. As the voltage increases, the voltage across the LED remains at 1.7v but the current through the LED increases and it gets brighter.
We now turn our attention to the current though the LED. As the current increases to 5mA, 10mA, 15mA, 20mA the brightness will increase and at 25mA, it will be a maximum. Increasing the supply voltage will simply change the colour of the LED slightly but the crystal inside the LED will start to overheat and this will reduce the life considerably.
This is just a simple example as each LED has a different CHARACTERISTIC VOLTAGE DROP and a different maximum current.
In the diagram below we see a LED on a 3v supply, 9v supply and 12v supply. The current-limiting resistors are different and the first circuit takes 6mA, the second takes 15mA and the third takes 31mA. But the voltage across the red LED is the same in all cases. This is because the LED creates the CHARACTERISTIC VOLTAGE DROP and this does not change.

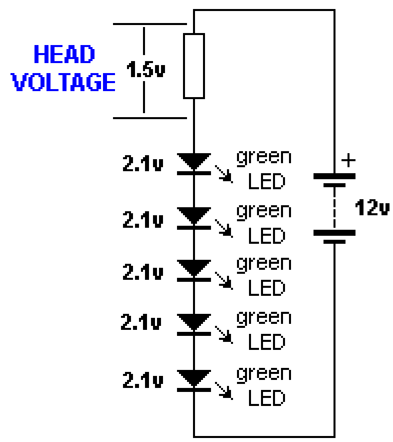


It does not matter if the resistor is connected above or below the LED. The circuits are the SAME in operation:



HEAD VOLTAGE

Now we turn our attention to the resistor.
As the supply-voltage increases, the voltage across the LED will be constant at 1.7v (for a red LED) and the excess voltage will be dropped across the resistor. The supply can be any voltage from 2v to 12v or more.
In this case, the resistor will drop 0.3v to 10.3v.
This is called **HEAD VOLTAGE - or HEAD-ROOM or OVERHEAD-VOLTAGE**. And the resistor is called the CURRENT-LIMIT resistor.
The following diagram shows **HEAD VOLTAGE:**



The voltage dropped across this resistor, combined with the current, constitutes wasted energy and should be kept to a minimum, but a small HEAD VOLTAGE is not advisable (such as 0.5v). The head voltage should be a minimum of 1.5v - and this only applies if the supply is fixed.
The head voltage depends on the supply voltage. If the supply is fixed and guaranteed not to increase or fall, the head voltage can be small (1.5v minimum).
But most supplies are derived from batteries and the voltage will drop as the cells are used.
Here is an example of a problem:
Supply voltage: 12v
7 red LEDs in series = 11.9v
Dropper resistor = 0.1v
As soon as the supply drops to 11.8v, no LEDs will be illuminated. (Sometimes the LEDs will illuminate because some LEDs will have a characteristic voltage that is slightly less than 1.7v and some will illuminate when the voltage is lower than 1.6v - but the brightness will reduce considerably.)
Example 2:
Supply voltage 12v
5 green LEDs in series @ 2.1v = 10.5v
Dropper resistor = 1.5v
The battery voltage can drop to 10.5v
But let's look at the situation more closely.
Suppose the current @ 12v = 25mA.
As the voltage drops, the current will drop.
At 11.5v, the current will be 17mA
At 11v, the current will be 9mA
At 10.5v, the current will be zero
You can see the workable supply drop is only about 1v.

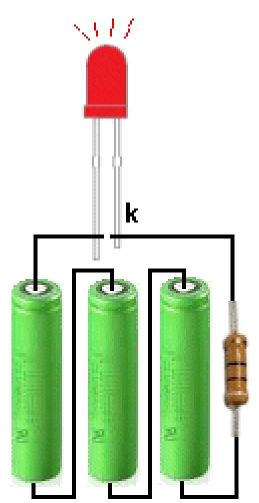
Many batteries drop 1v and still have over 80% of their energy remaining. That's why you need to design your circuit to have a large **HEAD VOLTAGE.**
A large **Head Voltage** is also needed when a plug-pack (wall wart) is used. These devices consist of a transformer, set of diodes and an electrolytic. The voltage marked on the unit is the voltage it will deliver when fully loaded. It may be 200mA, 300mA or 500mA. When this current is delivered, the voltage will be 9v or 12v. But if the current is less than the rated current, the output voltage will be higher. It may be 1v, 2v or even 5v higher.
This is one of the characteristics of a cheap transformer. A cheap transformer has very poor regulation, so to deliver 12v @ 500mA, the transformer produces a higher voltage on no-load and the voltage drops as the current increases.
You need to allow for this extra voltage when using a plug-pack so the LEDs do not take more than 20mA to 25mA.

Roger Mew contacted me asking for some suitable resistances for the HEAD VOLTAGE resistor.
Here is a list:

For 25mA current:
Use 56R for 1.5v drop.
Use 82R for 2v drop
Use 120R for 3v drop
Use 150R for 4v drop
Use 180R for about 5v drop

TESTING A LED

If the cathode lead of a LED cannot be identified, place 3 cells in series with a 220R resistor and illuminate the LED. 4.5v allows all types of LEDs to be tested as white LEDs require up to 3.6v. Do not use a multimeter as some only have one or two cells and this will not illuminate all types of LEDs. In addition, the negative lead of a multimeter is connected to the positive of the cells (inside the meter) for resistance measurements - so you will get an incorrect determination of the cathode lead.

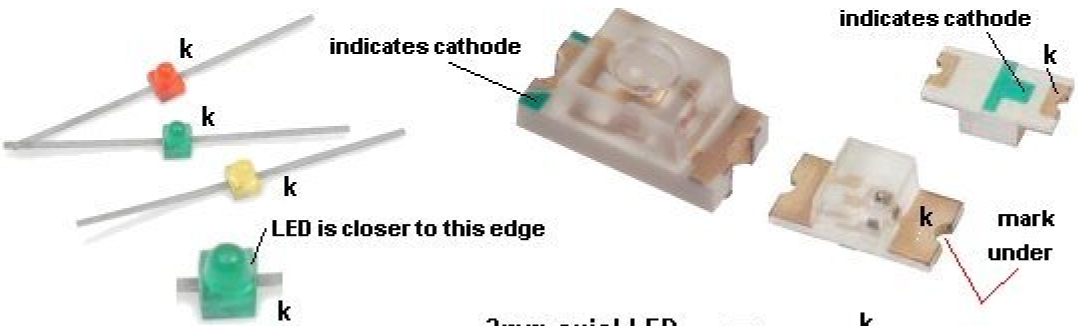


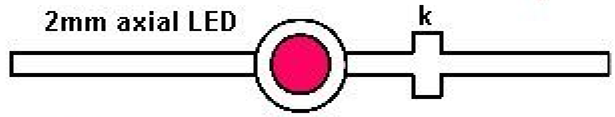
4.5v with resistor

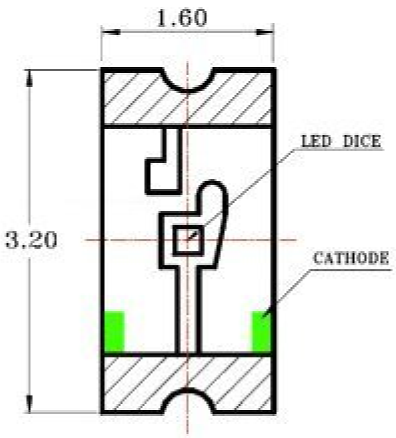
CIRCUIT TO TEST ALL TYPES OF LEDs

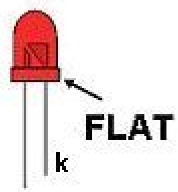
IDENTIFYING A LED

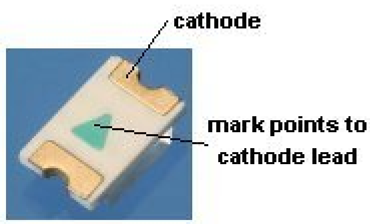
A LED does not have a "Positive" or "Negative" lead. It has a lead identified as the "Cathode" or Kathode" or "k". This is identified by a flat on the side of the LED and/or by the shortest lead.
This lead goes to the 0v rail of the circuit or near the 0v rail (if the LED is connected to other components).
Many LEDs have a "flat" on one side and this identifies the cathode. Some surface-mount LEDs have a dot or shape to identify the cathode lead and some have a cut-out on one end.
Here are some of the identification marks:

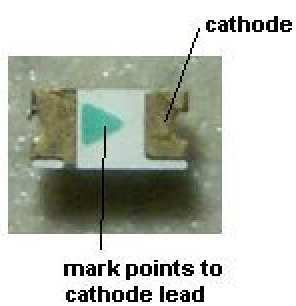


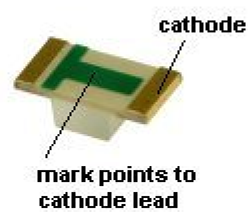


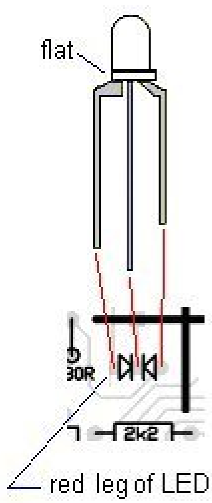












LEDs ARE CURRENT DRIVEN DEVICES

A LED is described as a CURRENT DRIVEN DEVICE. This means the illumination is determined by the amount of current flowing through it.
This is the way to see what we mean: Place a LED and 100R resistor in series and connect it to a variable power supply.
As the voltage is increased from 0v, to 1v, the LED will not produce any illumination, As the voltage from the

power-supply increases past 1v, the LED will start to produce illumination at about 1.6v to 1.7v (for a red LED). As the voltage is increased further, the illumination increases but the voltage across the LED does not increase. (It may increase 0.1v) but the brightness will increase enormously. That's why we say the LED is a CURRENT DRIVEN DEVICE.
The brightness of a LED can be altered by increasing or decreasing the current. The effect will not be linear and it is best to experiment to determine the best current-flow for the amount of illumination you want.
High-bright LEDs and super-bright LEDs will illuminate at 1mA or less, so the quality of a LED has a lot to do with the brightness. The life of many LEDs is determined at 17mA. This seems to be the best value for many types of LEDs.

1mA to 5mA LEDs

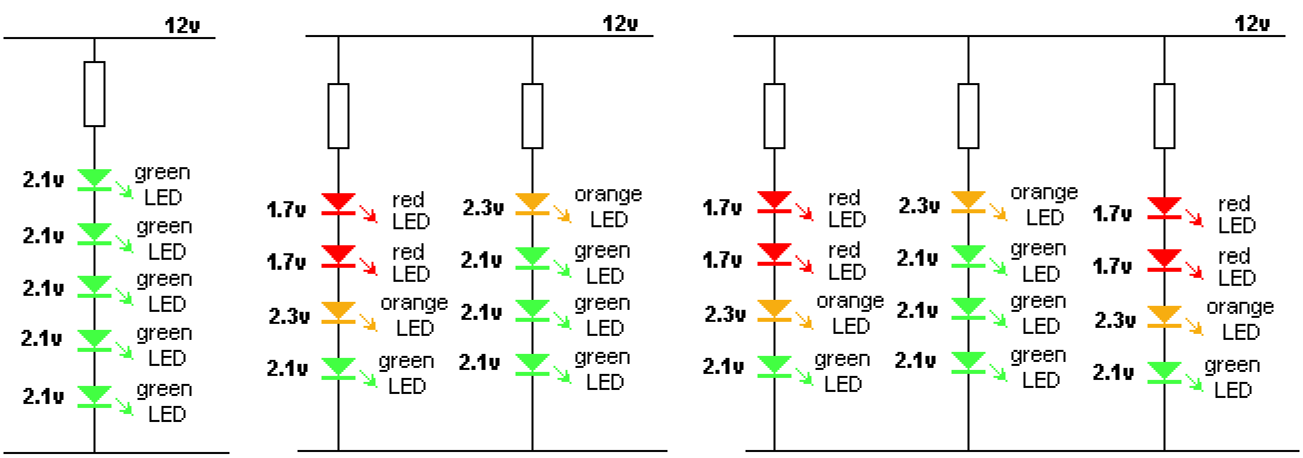
Some LEDs will produce illumination at 1mA. These are "high Quality" or "High Brightness" LEDs and the only way to check this feature is to test them @1mA as shown below.

THE 5v LED

Some suppliers and some websites talk about a 5v white or blue LED. Some LEDs have a small internal resistor and can be placed on a 5v supply. This is very rare.
Some websites suggest placing a white LED on a 5v supply. These LEDs have a characteristic voltage-drop of 3.6v and should not be placed directly on a voltage above 3.6v. If placed on a voltage below 3.6v, the LED will not glow very brightly. If you have a voltage EXACTLY 3.6v, you can connect the LED, but most voltages are higher than 3.6v and thus you need a resistor.
The only LED with an internal resistor is a FLASHING LED. These LEDs can be placed on a supply from 3.5v to 12v and flash at approx 2Hz. The LED is very weak on 3.5v but it flashing can be used to drive a powerful LED (see circuits section). It can also be used to produce a beep for a beeper FM transmitter.
NEVER assume a LED has an internal resistor. Always add a series resistor. Some high intensity LEDs are designed for 12v operation. These LEDs have a complete internal circuit to deliver the correct current to the LED. This type of device and circuitry is not covered in this eBook.

LEDs IN SERIES

LEDs can be placed in series providing some features are taken into account. The main item to include is a current-limiting resistor.
A LED and resistor is called a string. A string can have 1, 2, 3 or more LEDs.
Three things must be observed:
1. MAXIMUM CURRENT through each string = 25mA.
2. The CHARACTERISTIC VOLTAGE-DROP must be known so the correct number of LEDs are used in any string.
3. A DROPPER RESISTOR must be included for each string.
The following diagrams show examples of 1-string, 2-strings and 3-strings:

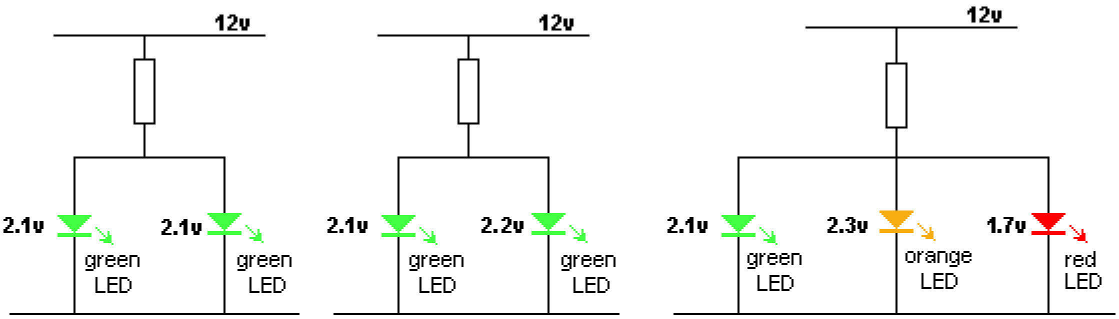


1 STRING 2 STRINGS 3 STRINGS

LEDs IN PARALLEL

LEDs CANNOT be placed in parallel - until you read this:
LEDs "generate" or "possess" or "create" a voltage across them called the CHARACTERISTIC VOLTAGE-DROP (when they are correctly placed in a circuit).
This voltage is generated by the type of crystal and is different for each colour as well as the "quality" of the LED (such as high-bright, ultra high-bright etc). This characteristic cannot be altered BUT it does change a very small amount from one LED to another in the same batch. And it does increase slightly as the current increases.
For instance, it will be different by as much as 0.2v for red LEDs and 0.4v for white LEDs from the same batch and will increase by as much as 0.5v when the current is increased from a minimum to maximum.

You can test 100 white LEDs @15mA and measure the CHARACTERISTIC VOLTAGE-DROP to see this range.
If you get 2 LEDs with identical CHARACTERISTIC VOLTAGE-DROP, and place them in parallel, they will each take the same current. This means 30mA through the current-limiting resistor will be divided into 15mA for each LED.
However if one LED has a higher CHARACTERISTIC VOLTAGE-DROP, it will take less current and the other LED will take considerably more. Thus you have no way to determine the "current-sharing" in a string of parallel LEDs. If you put 3 or more LEDs in parallel, one LED will start to take more current and will over-heat and you will get very-rapid LED failure. As one LED fails, the others will take more current and the rest of the LEDs will start to self-destruct. The reason why they take more current is this: the current-limit resistor will have been designed so that say 60mA will flow when 3 LEDs are in parallel. When one LED fails, the remaining LEDs will take 30mA each.
Thus **LEDs in PARALLEL** should be avoided.
Diagram **A** below shows two green LEDs in parallel. This will work provided the Characteristic Voltage Drop across each LED is the same.
In diagram **B** the Characteristic Voltage Drop is slightly different for the second LED and the first green LED will glow brighter.
In diagram **C** the three LEDs have different Characteristic Voltage Drops and the red LED will glow very bright while the other two LEDs will not illuminate. All the current will pass through the red LED and it will be damaged.
The reason why the red LED will glow very bright is this: It has the lowest Characteristic Voltage Drop and it will create a 1.7v for the three LEDs. The green and orange LEDs will not illuminate at this voltage and thus all the current from the dropper resistor will flow in the red LED and it will be destroyed.

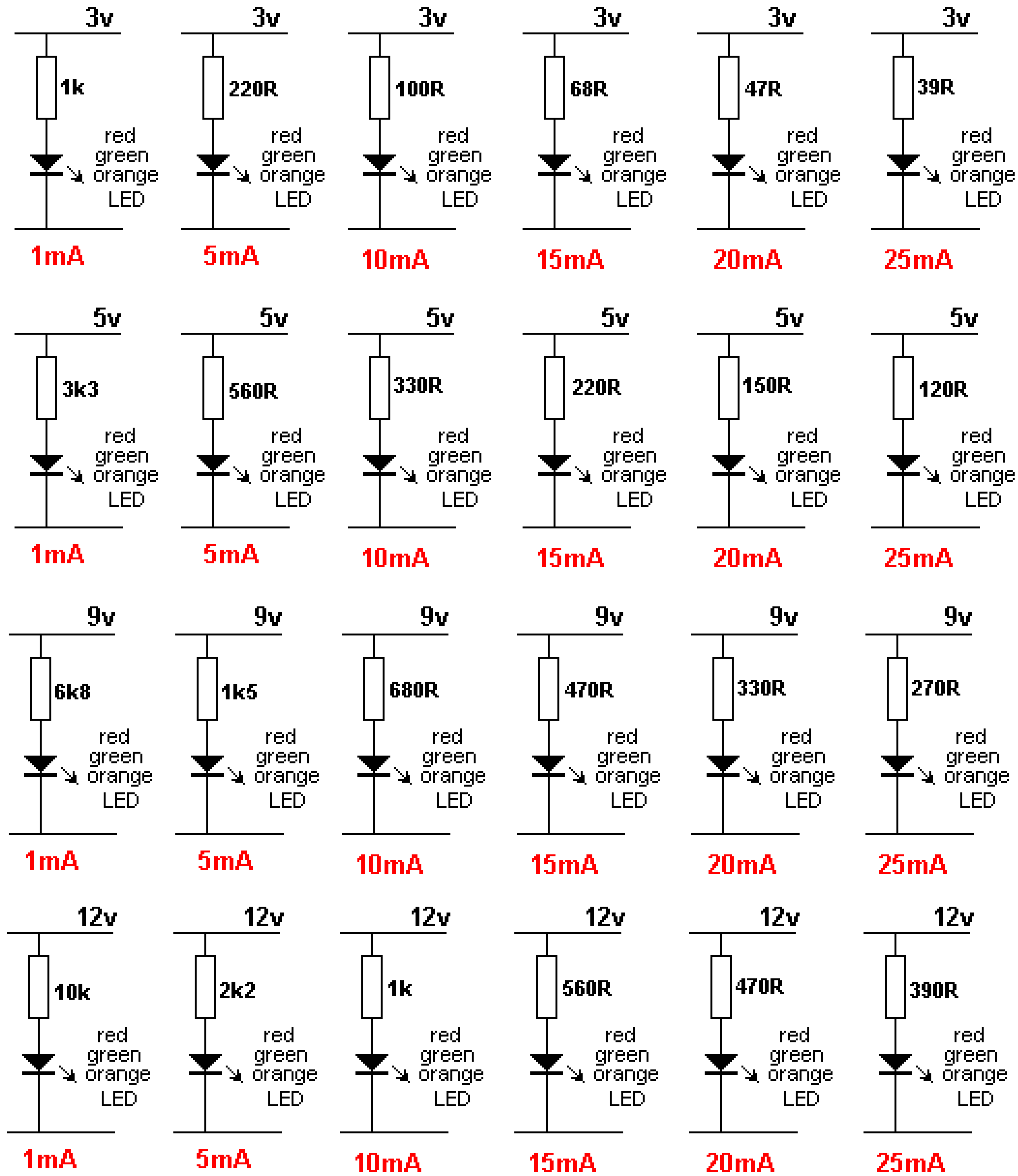


A
This circuit will work
B
2.1v LED will be brighter
C
red LED will glow and get damaged

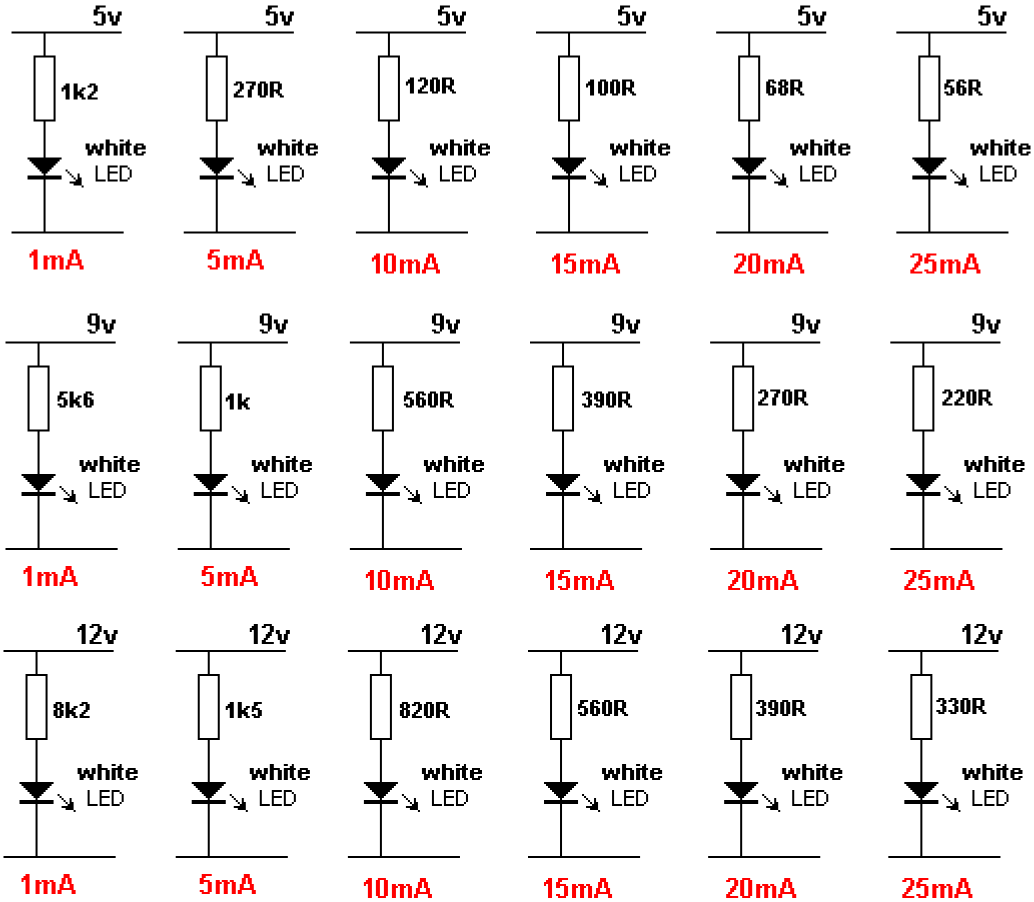
THE RESISTOR

The value of the current limiting resistor can be worked out by Ohms Law.
Here are the 3 steps:
1. Add up the voltages of all the LEDs in a string. e.g: 2.1v + 2.3v + 2.3v + 1.7v = 8.4v
2. Subtract the LED voltages from the supply voltage. e.g: 12v - 8.4v = 3.6v
3. Divide the 3.6v (or your voltage) by the current through the string.
for 25mA: 3.6/.025 =144 ohms
for 20mA: 3.6/.02 = 180 ohms
for 15mA: 3.6/.015 = 250 ohms
for 10mA: 3.6/.01 = 360 ohms
This is the value of the current-limiting resistor.

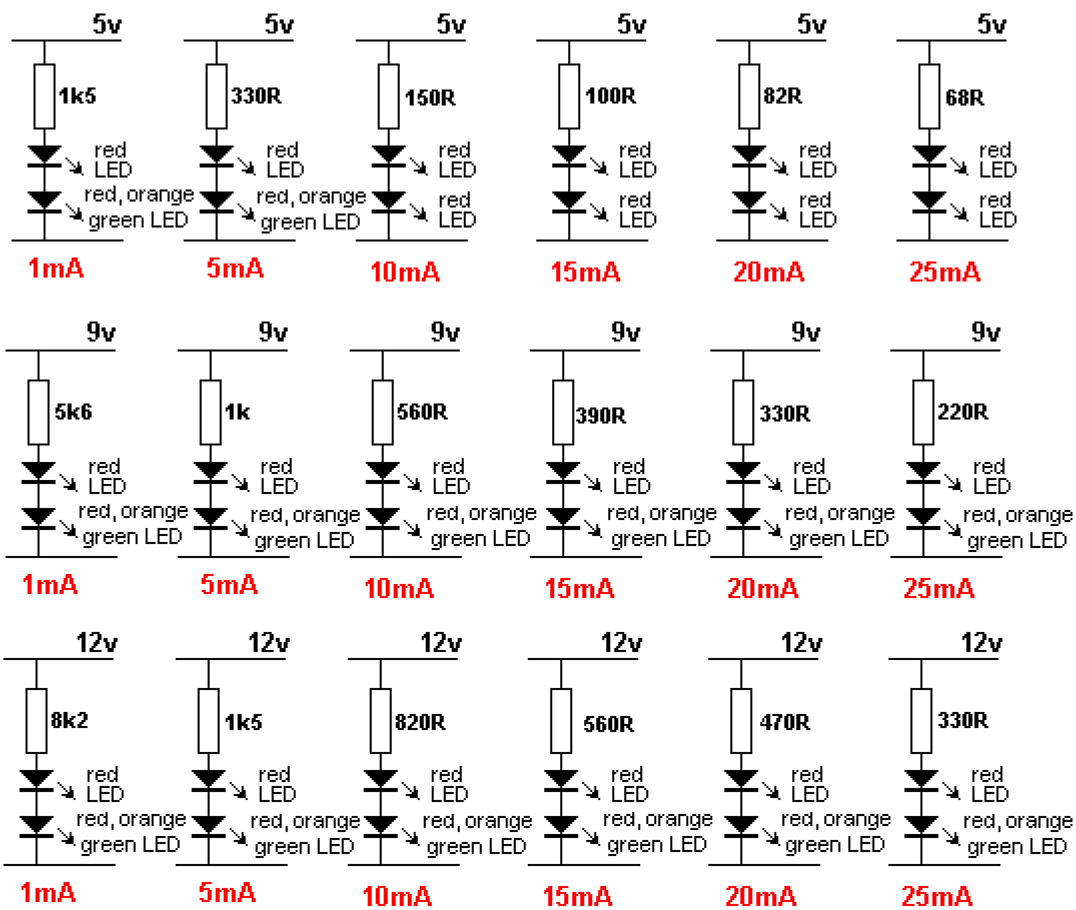
Here is a set of strings for a supply voltage of 3v to 12v and a single LED:



Here is a set of strings for a supply voltage of 5v to 12v and a white LED:



Here is a set of strings for a supply voltage of 5v to 12v and two LEDs:



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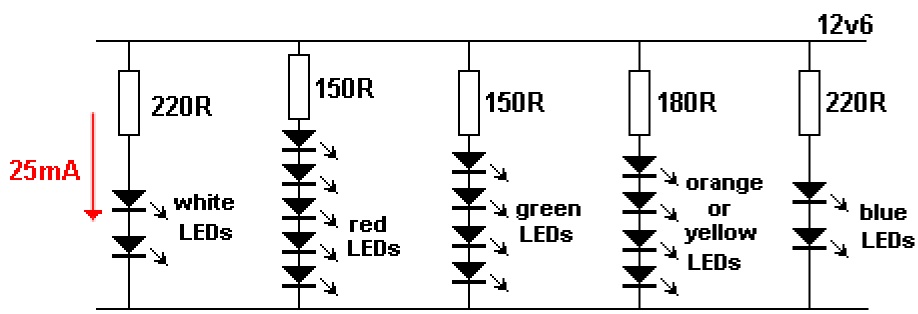
LEDS ON 12v - for cars and trucks

When connecting LEDs to cars and trucks, you have to allow for an increase in voltage during the time when the battery is being charged. Normally the battery sits at 12.6v, but when charging, it can rise to 13.5v or slightly higher.
If you put 3 white LEDs in series, the "head" voltage will be about 1.8v when the battery is 12.6v, but increase to 2.7v when it is charging.
This will increase the current through the LEDs by about 50% and will be noticeable as the brightness will increase considerably. The extra current may also damage the LEDs.
To keep an even brightness, we suggest using strings of LEDs with just two white LEDs and 220R 0.25watt resistors as shown in the following diagram.
Red, green, orange, yellow and blue LEDs have a different characteristic voltage across them when illuminated and so you can have more LEDs in a single string, with a suitable current-limiting resistor.
Here is the answer for each colour:



25mA is the MAXIMUM for 3mm and 5mm ordinary, high-bright or Super-bright LEDs.

LED series/parallel array wizard

The **LED series/parallel array wizard** below, is a calculator that will help you design large arrays of single-colour LEDs.
This calculator has been designed by **Rob Arnold** and you will be taken to his site: http://led.linear1.org/led.wiz when you click: **Design my array**
The wizard determines the current limiting resistor value for each string of the array and the power consumed. All you need to know are the specs of your LED and how many you'd like to use. The calculator only allows one LED colour to be used. For mixed colours, you will have to use the 3 steps explained above.
The result is not always correct. Read the discussion below: "**THE DANGERS OF USING A "LED WIZARD"** to understand the word "HEAD VOLTAGE." The HEAD VOLTAGE should be as high as possible to allow for the differences in Characteristic Voltage and the variations in power supply voltage.

Source voltage

diode forward voltage

diode forward current (mA)

number of LEDs in your array

View output as: ASCII schematic wiring diagram

help with resistor colour codes

Design my array

Resistor Calculator

Use this JavaScript resistor calculator to work out the value of the current-limiting resistor:

Source voltage	=	12.6
LED forward voltage drop	=	3.6
LED current in milliamps	=	25
Current-limiting resistance in Ohms	=	
Closest 5% Resistor	=	
Resistor wattage	=	
Actual current	=	
Power dissipated by LED (watts)	=	
Power dissipated by resistor (watts)	=	

LED VOLTAGE AND CURRENT

LED characteristics are very broad and you have absolutely no idea of any value until you test the LED.
However here are some of the generally accepted characteristics:

Lens Color	Forward Voltage		Forward Current	
	Typical	Maximum	Typical	Maximum
RED	1.6 Volts	2.0 Volts	.010 Amp	.020 Amp
GREEN	2.2 Volts	3.0 Volts	.010 Amp	.020 Amp
YELLOW	2.2 Volts	3.0 Volts	.010 Amp	.020 Amp
* Blue * (Note)	3.8 Volts	4.5 Volts	.020 Amp	.020 Amp
WHITE	3.2 – 3.6 Volts	3.8 Volts	.010 Amp	.020 Amp

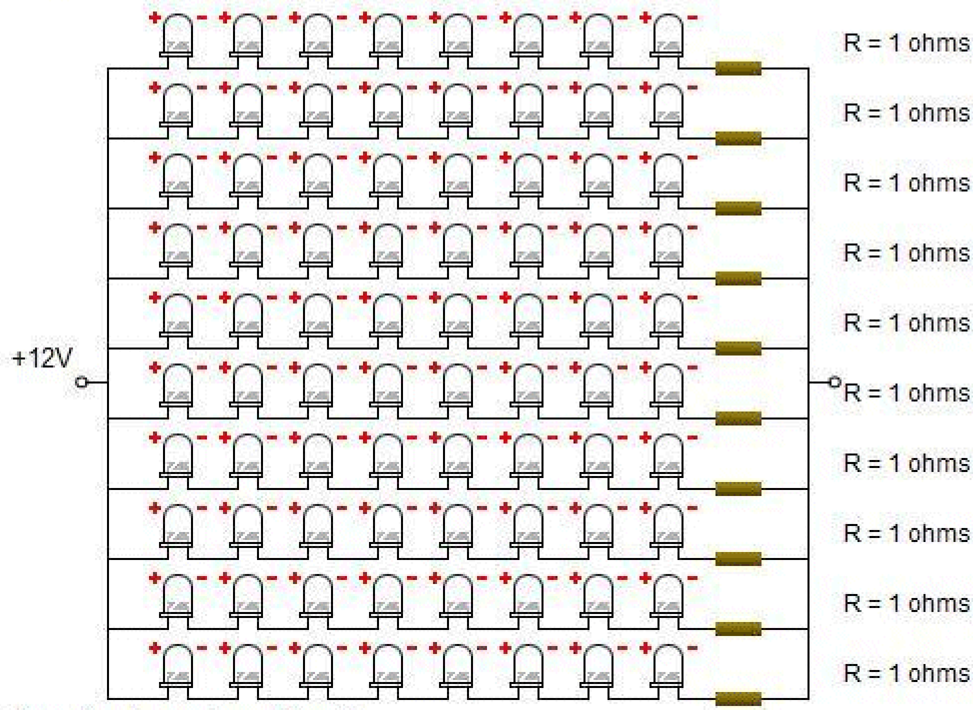
NOTE 1: The above Voltage and Current ratings are based on several everyday generic LEDS in the 3 mm and 5 mm size ranges.

NOTE 2: Blue color LEDS may typically have forward working voltages exceeding those used in the above example. Forward working voltages for some Blue color LEDS may also fall in the 4.9 to 5.5 Volt range.

THE DANGERS OF USING A "LED WIZARD"

You can find a LED WIZARD on the web that gives you a circuit to combine LEDs in series and/or parallel for all types of arrays.
Here is an example, provided by a reader. Can you see the major fault?

Solution 0: 8 x 10 array uses 80 LEDs exactly



The wizard says: In solution 0:

- each 1 ohm resistor dissipates 0.4 mW
- the wizard thinks 1/4W resistors are fine for your application
- together, all resistors dissipate 4 mW
- together, the diodes dissipate 2400 mW
- total power dissipated by the array is 2404 mW
- the array draws current of 200 mA from the source.

The characteristic voltage (the colour of the LED) is not important in this discussion. Obviously white LEDs will not work as they require 3.4v to 3.6v to operate.
The main fault is the dropper resistor.
Read our article on LEDs.
The most important component is the DROPPER RESISTOR.
It must allow for the difference between the maximum and minimum supply voltage and ALSO the maximum and minimum CHARACTERISTIC VOLTAGE of the string of LEDs.
When we say a red LED has a CHARACTERISTIC VOLTAGE of 1.7v, we need to measure the exact maximum and minimum value for the LEDs we are installing.
Some high-bright and super-high-bright LEDs have a Characteristic Voltage of 1.6v to 1.8v and this will make a big difference when you have 8 LEDs in series.
Secondly, the 12v supply may rise to 13.6v when the battery is being charged and fall to 10.8v at the end of its life.
Thirdly, you need to know the current required by the LEDs.
The normal value is 17mA for long life.
This can rise to 20mA but must not go higher than 25mA
You should also look at the minimum current. Many high-bright LEDs will perform perfectly on 5-10mA and become TOO BRIGHT on 20mA.
As you can see, it is much more complex than a WIZARD can handle.
That's why it produced the absurd result above.
The maximum characteristic voltage for 8 red LEDs is 8x1.8v = 14.4v
This means you can only put 6 LEDs in series. = 10.8v
The LEDs will totally die when the battery reaches 10.8v
The value of the dropper resistor for 6 LEDs and a supply of 12v @20mA = 60 ohms. When the battery voltage rises to 13.6v during charging, the current will be: 46mA. This is too high.
The CURRENT LIMITING resistor is too low.
We need to have a higher-value CURRENT LIMITING resistor and fewer LEDs.
Use 5 LEDs:
The characteristic voltage for 5 LEDs will be: 5 x 1.7v = 8.5v
Allow a current of 20mA when the supply is 12.6v   Dropper resistor = 200 ohms.
Current at 10.8v will be 11mA. And current at 13.6v will be 25mA
Now you can see why the value of the CURRENT LIMITING RESISTOR has to be so high.

SOLDERING LEDs

LEDs are the most heat-sensitive device of all the components.
When soldering surface-mount LEDs, you should hold the LED with tweezers and "tack" one end. Then wait for the LED to cool down and solder the other end very quickly. Then wait a few seconds and completely solder the first end. Check the glow of each LED with 3 cells in series and a 220R resistor. If you have overheated the LED, its output will be dim, or a slightly different colour, or it may not work at all. They are extremely sensitive to heat - mainly because the crystal is so close to the soldering iron.

HIGH-BRIGHT LEDs

LEDs have become more efficient over the past 25 years.
Originally a red LED emitted 17mcd @20mA. These LEDs now emit 1,000mcd to 20,000mcd @20mA.
This means you can lower the current and still produce illumination. Some LEDs operate on a current as low as 1mA.
Some high-bright white LEDs are TOO BRIGHT to look at and will hurt your eyes.
It is impossible to give any information on the output required for any particular application.
Old LEDs require 15mA to produce a dull illumination that does not emit out of the opaque red/green/orange LED and is just a waste of 15mA.
You can get a high-bright LED to produce a higher brightness at 1mA to 5mA and save a lot of battery energy.
Design all your projects using high-bright LEDs with a current of 1mA to 10mA.

LEDs as LIGHT DETECTORS

LEDs can also be used to detect light.
Green LEDs are the best, however all LEDs will detect light and produce a voltage equal to the CHARACTERISTIC VOLTAGE-DROP, providing they receive sufficient light. The current they produce is miniscule however high-bright and super-bright LEDs produce a higher output due to the fact that their crystal is more efficient at converting light into electricity.
The Solar Tracker project uses this characteristic to track the sun's movement across the sky.

BI-COLOUR, TRI-COLOUR, FLASHING LEDS and 7-colour LEDs

LEDs can also be obtained in a range of novelty effects as well as a red and green LED inside a clear or opaque lens. You can also get red, blue, white, green or any combination inside a LED with 2 leads.
Simply connect these LEDs to a 6v supply and 330R series dropper resistor to see the effects they produce.
Some LEDs have 3 leads and the third lead needs to be pulsed to change the pattern.
Some LEDs can be reversed to produce a different colour. These LEDs contain red and green and by reversing the voltage, one or the other colour will illuminate.
When the voltage is reversed rapidly, the LED produces orange.
Sometimes it is not convenient to reverse the voltage to produce orange.
In this case three leaded LEDs are available to produce red, green and orange.

FLASHING LEDs

Flashing LEDs contain a chip and inbuilt current-limiting resistor. They operate from 3.5v to 12v. The flash-rate will alter slightly on different supply voltage. You can get 3mm and 5mm versions as well as high-bright types and surface-mount.

NOVELTY LEDs

Novelty LEDs can have 2 or three leads. They contain a microcontroller chip, inbuilt current-limiting resistor and two or three colours.
The two leaded LEDs cycle through a range of colours, including flashing and fading.
The three leaded LEDs have up to 16 different patterns and the control lead must be taken from 0v to rail volts to activate the next pattern.

LEDs LEDs LEDs

There are hundreds of circuits that use a LED or drive a LED or flash a LED and nearly all the circuits in this eBook are different.
Some flash a LED on a 1.5v supply, some use very little current, some flash the LED very brightly and others use a flashing LED to create the flash-rate.
You will learn something from every circuit. Some are interesting and some are amazing. Some consist of components called a "building Block" and they can be added to other circuits to create a larger, more complex, circuit.
This is what this eBook is all about.
It teaches you how to build and design circuits that are fun to see working, yet practical.

You will learn a lot . . . . even from these simple circuits.

Colin Mitchell
TALKING ELECTRONICS.
talking@tpg.com.au

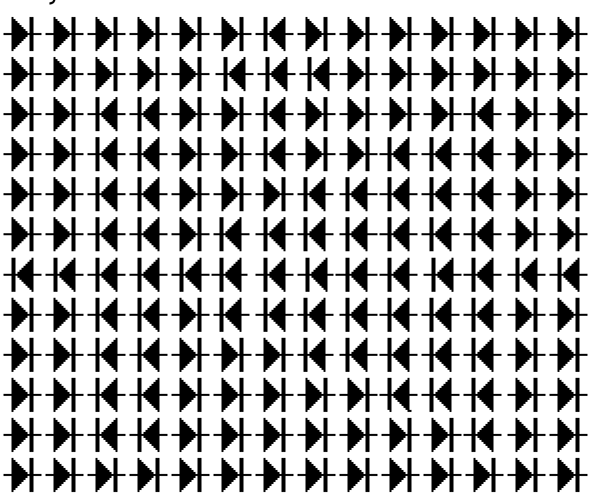
SI NOTATION

All the schematics in this eBook have components that are labelled using the **System International** (SI) notation system. The SI system is an easy way to show values without the need for a decimal point. Sometimes the decimal point is difficult to see and the SI system overcomes this problem and offers a clear advantage.
Resistor values are in ohms (R), and the multipliers are: k for kilo, M for Mega. Capacitance is measured in farads (F) and the sub-multiples are u for micro, n for nano, and p for pico. Inductors are measured in Henrys (H) and the sub-multiples are mH for milliHenry and uH for microHenry.
A 10 ohm resistor would be written as 10R and a 0.001u capacitor as 1n.
Some countries use the letter "E" to represent Ohm, such as 100E = 100 ohms = 100R.
The markings on components are written slightly differently to the way they are shown on a circuit diagram (such as 100p on a circuit and 101 on the capacitor or 10 on a capacitor and 10p on a diagram) and you will have to look on the internet under **Basic Electronics** to learn about these differences.

We have not provided lengthy explanations of how any of the circuits work. This has already been covered in TALKING ELECTRONICS Basic Electronics Course, and can be obtained on a CD for $10.00 (posted to anywhere in the world)

For photos of nearly every electronic component, see this website:
https://www.egr.msu.edu/eceshop/Parts_Inventory/totalinventory.php

How good is your power of observation?
Can you find the LED:



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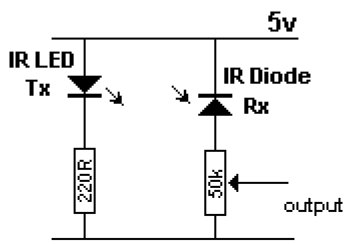
INFRARED LED

Infrared LEDs are just like ordinary LEDs but the light output cannot be seen. To view an infrared LEDs, turn it on with the appropriate battery and dropper resistor and view it with a camera. You will see the illumination on the screen.
Infrared LEDs are sometimes clear and sometimes black. They operate just like a red LED with the same characteristic voltage-drop of about 1.7v.
Sometimes an infrared LED is pulsed with a high current for a very short period of time but the thing to remember is the wattage-dissipation of a 5mm LED is about 70mW. This means the constant-current should be no more than 40mA.
Infrared LEDs are also called TRANSMITTING LEDs as they emit light. These are given the term **Tx** (for transmitting). An infrared LED can be connected to a 5v supply via a 220R current-limiting resistor for 15mA current.
Infrared receivers (**Rx**) can look exactly like infrared LEDs, but they do not emit IR light. They detect Infrared illumination and must be connected the correct way in a

circuit.
They have a very high resistance when no receiving IR illumination and the resistance decreases as the illumination increases.
This means they are connected to a 5v supply via a resistor and when the resistance of the infrared receiver decreases, current will flow thought it and the resistor. This will produce a voltage across the resistor and this voltage is fed to the rest of the circuit.

Here is a circuit to show how to connect an infrared LED and Infrared (diode) receiver:



You cannot use an IR LED as a receiver or an Infrared diode as an illuminator. They are constructed differently. An infrared LED has a characteristic voltage drop of 1.7v
An Infrared receiver does not have a characteristic voltage-drop. It has a high resistance when not illuminated and a low resistance when it receives illumination.

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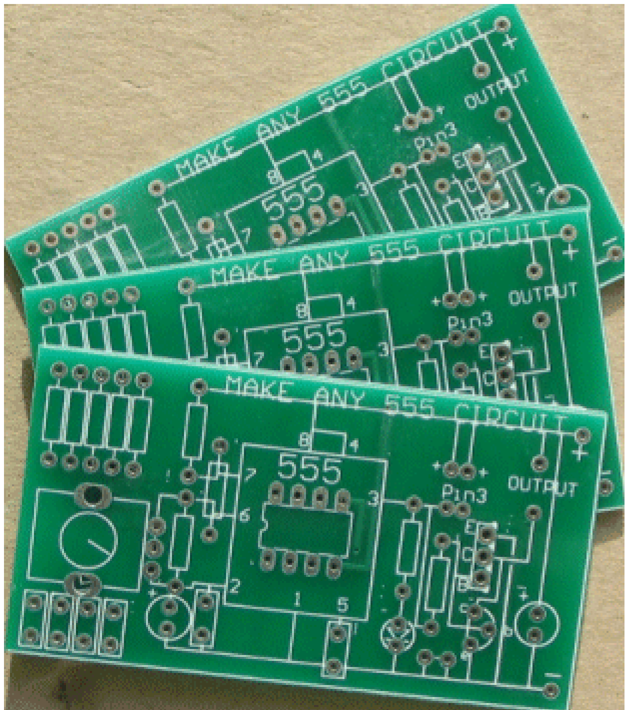
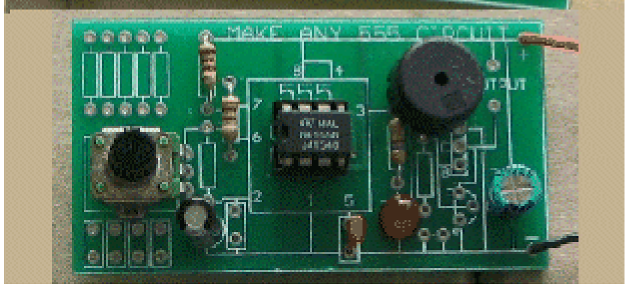
POWERING A PROJECT

The safest way to power a project is with a battery. Each circuit requires a voltage from 3v to 12v. This can be supplied from a set of AA cells in a holder or you can also use a 9v battery for some projects.
If you want to power a circuit for a long period of time, you will need a "power supply."
The safest power supply is a Plug Pack (wall-wort, wall wart, wall cube, power brick, plug-in adapter, adapter block, domestic mains adapter, power adapter, or AC adapter). Some plug packs have a switchable output voltage: 3v, 6v, 7.5v, 9v, 12v) DC with a current rating of 500mA. The black lead is negative and the other lead with a white stripe (or a grey lead with a black stripe) is the positive lead.
This is the safest way to power a project as the insulation (isolation) from the mains is provided inside the adapter and there is no possibility of getting a shock.
The rating "500mA" is the maximum the Plug Pack will deliver and if your circuit takes just 50mA, this is the current that will be supplied. Some pluck packs are rated at 300mA or 1A and some have a fixed output voltage. All these plug packs will be suitable.
Some Plug Packs are marked "12vAC." This type of plug pack is not suitable for these circuits as it does not have a set of diodes and electrolytic to convert the AC to DC. All the circuits in this eBook require DC.

BUY NOW





A set of components for **MAKE ANY 555 PROJECT** is just $5.00 extra

The parts include:
2 - 220R
2 - 1k
2 - 4k7
2 - 10k
2 - 33k
2 - 47k
2- 100k
2 - 1M
1 - 10k mini pot
1 - 100k mini pot
2 - 10n
2 - 100n
1 - 10u electrolytic
2- 100u electrolytic
1 - 1N4148 signal diodes
3 - BC547 transistors
3 - 555 timer chips
3 - 8 pin IC sockets
1 - red LED
1 - green LED
1 - orange LED
3 - mini piezos
1 - LDR (Light Dependent Resistor)
3 - slim tactile push buttons

3 x Make any 555 Project PC boards plus components: $15.00 (post FREE)

PROJECTS

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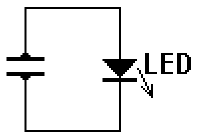
Simplest LED Circuit

Connect a LED to a piezo diaphragm and tap the piezo with a screwdriver at the centre of the disc and the LED will flash very briefly.



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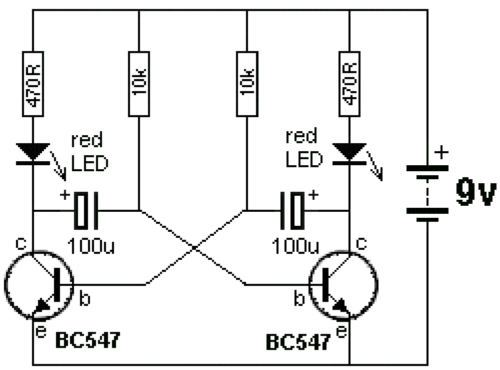

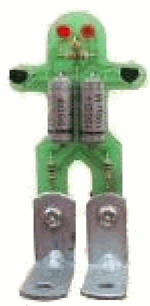

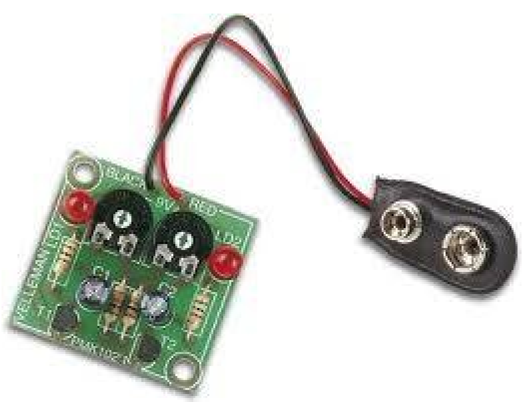

ROBOT MAN

This multivibrator circuit will flash the Robot Man's eyes as shown in the photo. The kit of components is available from Talking Electronics for $8.50 plus postage. Send an email to find out the cost of postage: talking@tpg.com.au

Here is the circuit from **Velleman Kits.** The two 10k resistors are replaced with a **resistor and pot** so the "flip flop" can be altered.

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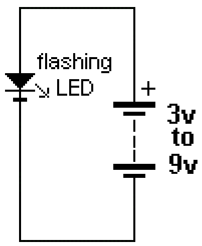
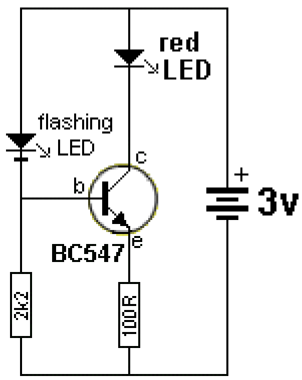
FLASHING A LED

These 7 circuits flash a LED using a supply from 1.5v to 12v.
They all have a different value of efficiency and current consumption. You will find at least one to suit your requirements.
The simplest way to flash a LED is to buy a FLASHING LED as shown in figure **A**. It will work on 3v to 9v but it is not very bright - mainly because the LED is not high-efficiency.
A Flashing LED can be used to flash a super-bright red LED, as shown in figure **B**.
Figure **C** shows a flashing LED driving a buffer transistor to flash a white LED. The circuit needs 4.5v - 6v.
Figure **D** produces a very bright flash for a very short period of time - for a red, green, orange or white

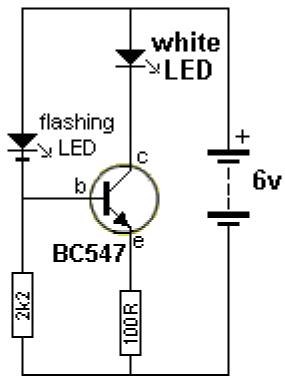
LED.
Figure **E** uses 2 transistors to produce a brief flash - for a red, green, orange or white LED.
Figure **F** uses a single cell and a voltage multiplying arrangement to flash a red or green LED.
Figure **G** flashes a white LED on a 3v supply.



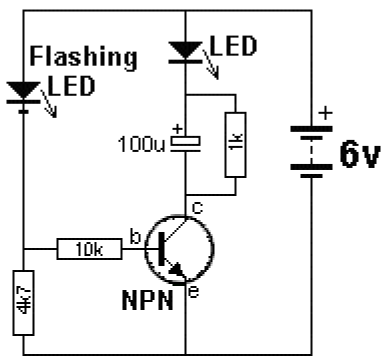
A



B



C



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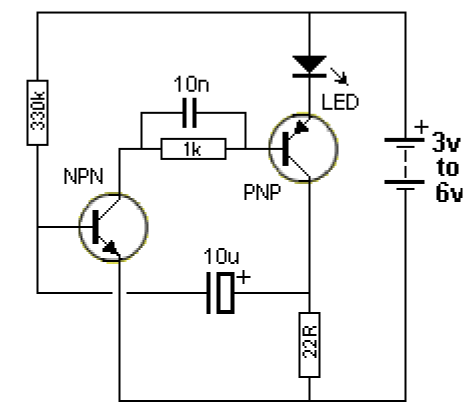

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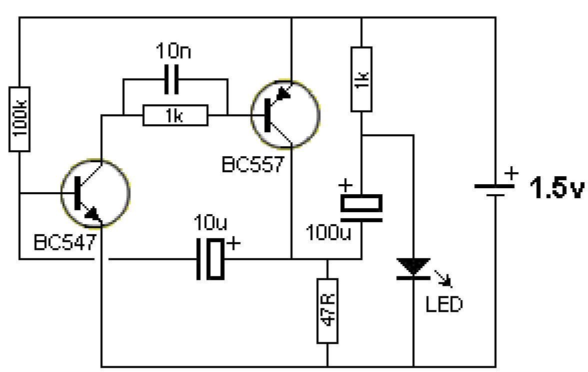
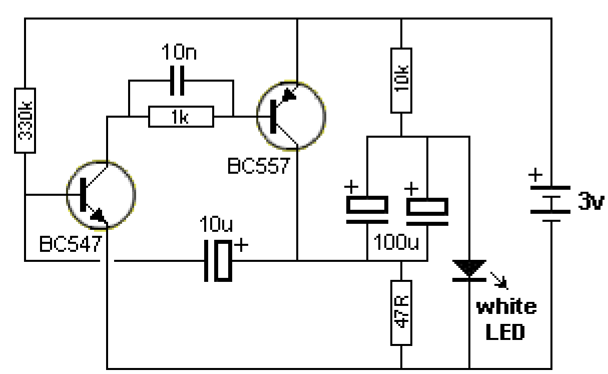


1.5v LED FLASHER

F



WHITE LED FLASHER

G

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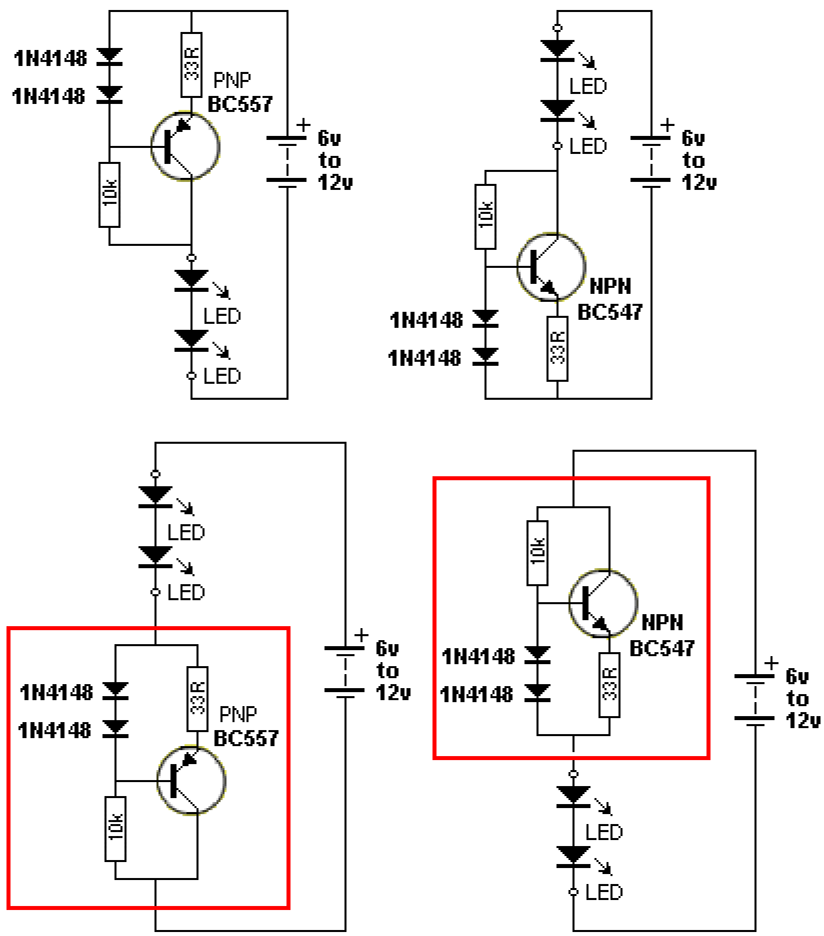
CONSTANT CURRENT

These four circuits delivers a constant 12mA to any number of LEDs connected in series (to the terminals shown) in the following arrangements.
The circuits can be connected to 6v, 9v or 12v and the brightness of the LEDs does not alter.
You can connect:
1 or 2 LEDs to 6v,

1, 2 or 3 LEDs to 9v or
1, 2, 3 or 4 LEDs to 12v.
The LEDs can be any colour.
The constant-current section can be considered as a MODULE and can be placed above or below the load:



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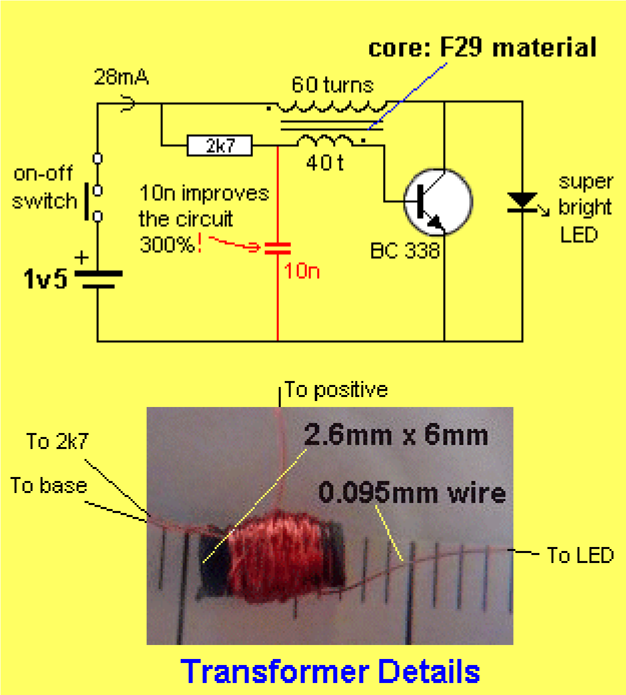
WHITE LED on 1.5v SUPPLY

This circuit will illuminate a white LED using a single cell.
See LED Torch Circuits article for more details.



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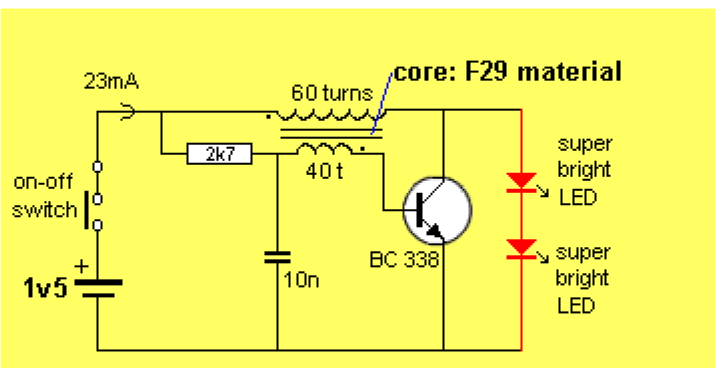
2 WHITE LEDs on 1.5v SUPPLY

This circuit will illuminate two white LEDs using a single cell.
See LED Torch Circuits article for more details.



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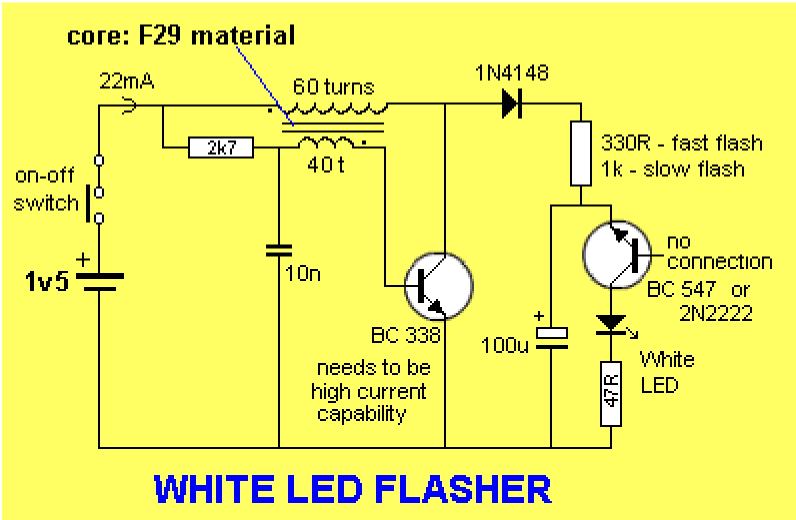
WHITE LED FLASHER

This circuit will flash a white LEDs using a single cell.
See LED Torch Circuits article for more details.



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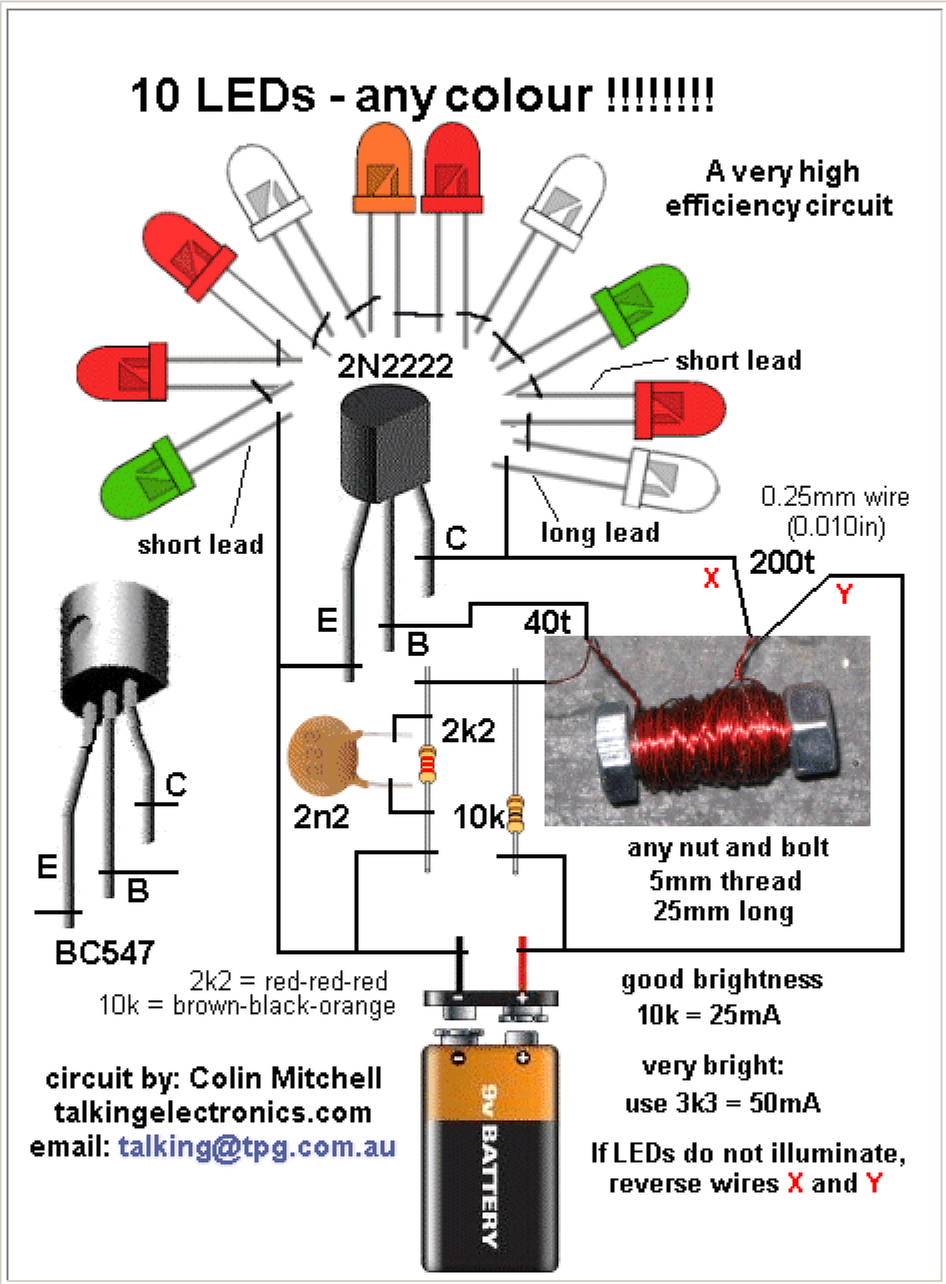
10 LEDs on a 9v BATTERY

This circuit will illuminate 10 LEDs on a 9v battery.
It was designed in response to a readers request:


10 LEDs - any colour !!!!!!!!
A very high efficiency circuit
2N2222
short lead
short lead
long lead
C
E
B
0.25mm wire
(0.010in)
200t
X
Y
40t
2k2
2n2
10k
any nut and bolt
5mm thread
25mm long
C
E
B
BC547
2k2 = red-red-red
10k = brown-black-orange
good brightness
10k = 25mA
very bright:
use 3k3 = 50mA
If LEDs do not illuminate,
reverse wires X and Y
circuit by: Colin Mitchell
talkingelectronics.com
email: talking@tpg.com.au
9v BATTERY

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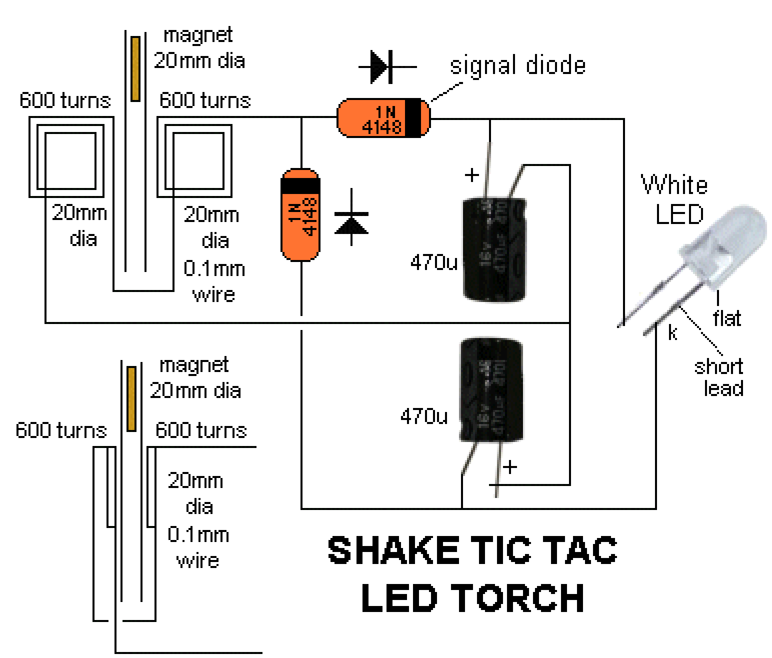

SHAKE TIC TAC LED TORCH

In the diagram, it looks like the coils sit on the "table" while the magnet has its edge on the table. This is just a diagram to show how the parts are connected. The coils actually sit flat against the slide (against the side of the magnet) as shown in the diagram: The output voltage depends on how quickly the magnet passes from one end of the slide to the other. That's why a rapid shaking produces a higher voltage. You must get the end of the magnet to fully pass though the coil so the voltage will be a maximum. That's why the slide extends past the coils at the top and bottom of the diagram.

The circuit consists of two 600-turn coils in series, driving a voltage doubler. Each coil produces a positive and negative pulse, each time the magnet passes from one end of the slide to the other.
The positive pulse charges the top electrolytic via the top diode and the negative pulse charges the lower electrolytic, via the lower diode.
The voltage across each electrolytic is combined to produce a voltage for the white LED. When the combined voltage is greater than 3.2v, the LED illuminates. The electrolytics help to keep the LED illuminated while the magnet starts to make another pass.

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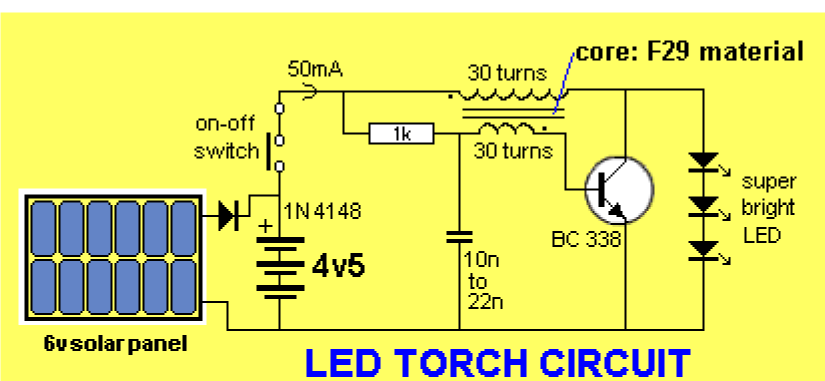
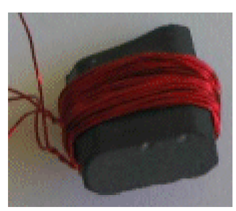
LED FLASHLIGHT

Here is a request from one of our readers:
I want to build a solar powered flashlight. It will contain 3-AAs nickel hydride batteries of 1.2v each. I want many ultrabright white LEDS @ 25mA. I also need a voltage regulator circuit so the batteries won't overcharge. The batteries are 800 mAH capacity. I need a high-low beam too. Do you have a schematic for this?
Here is a very simple circuit.
The circuit produces a voltage higher than 3.6v, from a supply of 4.5v to 6v to illuminate 3 super-bright LEDs in series.
The flyback transformer consists of 30 turns and 30 turns wound on an old ferrite antenna slab.
Reverse the feedback winding if the LEDs do not illuminate.
Some solar panels will drain a small current from the battery when not illuminated, so a "protection diode" can be added.





The fly-back transformer 30turns & 30 turns on any ferrite core

You can also use a single 3.7v Li-Ion cell.
These are available on eBay for $2.00 post free. Solar panels are also available on eBay.

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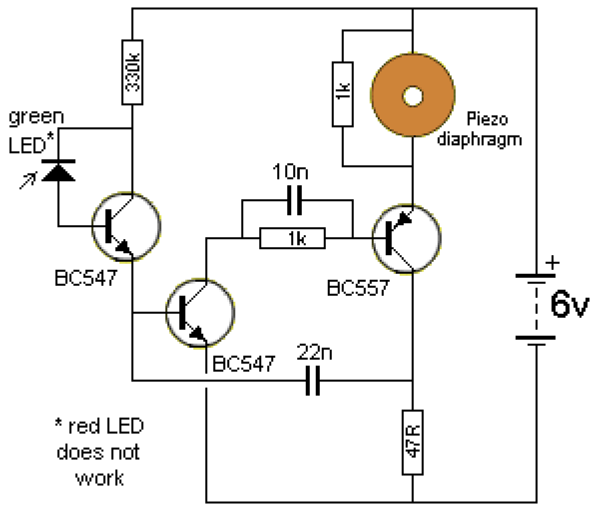

LED DETECTS LIGHT

The LED in this circuit will detect light to turn on the oscillator. Ordinary red LEDs do not work. But green LEDs, yellow LEDs and high-bright white LEDs and high-bright red LEDs work very well.
The output voltage of the LED is up to 600mV when detecting very bright illumination. When light is detected by the LED, its resistance decreases and a very small current flows into the base of the first transistor. The transistor amplifies this current about 200 times and the resistance between collector and emitter decreases. The 330k resistor on the collector is a current limiting resistor as the middle transistor only needs a very small current for the circuit to oscillate. If the current is too high, the circuit will "freeze."
The piezo diaphragm does not contain any active components and relies on the circuit to drive it to produce the tone.

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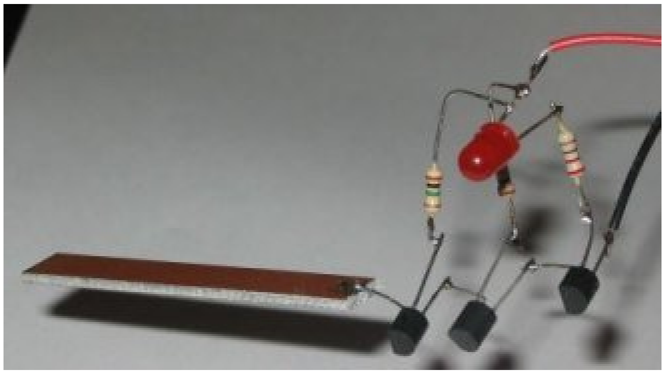
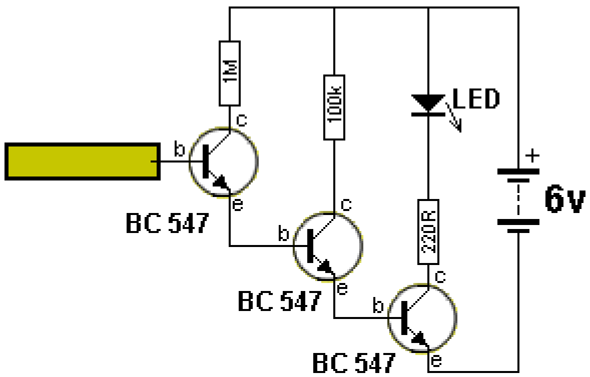
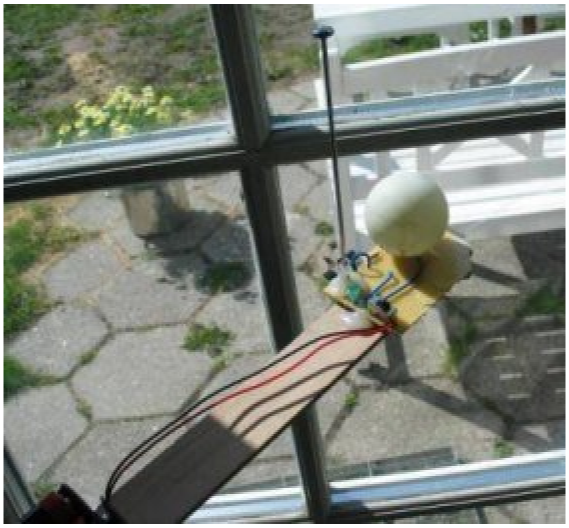


8 MILLION GAIN!

This circuit is so sensitive it will detect "mains hum." Simply move it across any wall and it will detect where the mains cable is located. It has a gain of about 200 x 200 x 200 = 8,000,000 and will also detect static electricity and the presence of your hand without any direct contact. You will be amazed what it detects! There is static electricity EVERYWHERE! The input of this circuit is classified as very high impedance.



Here is a photo of the circuit, produced by a



constructor.

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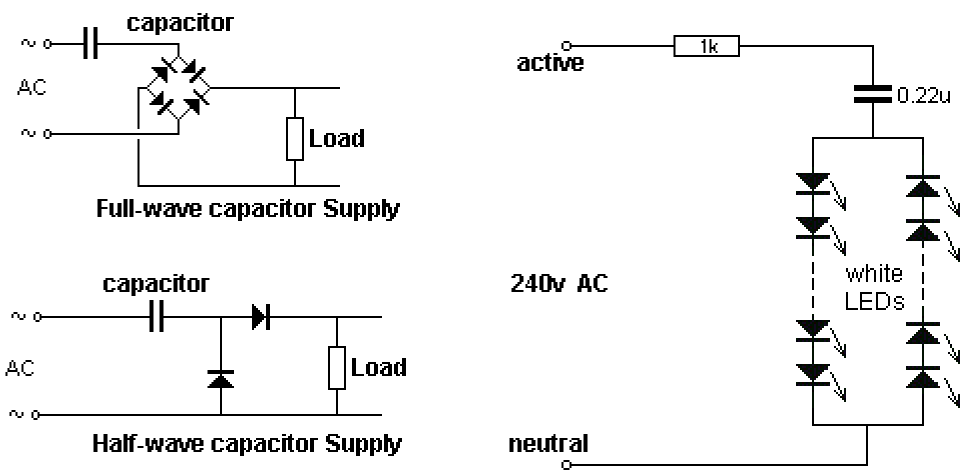


LEDs on 240v

I do not like any circuit connected directly to 240v mains. However Christmas tress lights (globes) have been connected directly to the mains for 30 years without any major problems.
Insulation must be provided and the lights (LEDs) must be away from prying fingers.
You need at least 50 LEDs in each string to prevent them being damaged via a surge through the 1k resistor - if the circuit is turned on at the peak of the waveform. As you add more LEDs to each string, the current will drop a very small amount until eventually, when you have 90 LEDs in each string, the current will be zero.
For 50 LEDs in each string, the total characteristic voltage will be 180v so that the peak voltage will be 330v - 180v = 150v. Each LED will see less than 7mA peak during the half-cycle they are illuminated (because the voltage across the 0.22u is 150v and this voltage determines the current-flow). The 1k resistor will drop 7v - since the RMS current is 7mA (7mA x 1,000 ohms = 7v). No rectifier diodes are needed. The LEDs are the "rectifiers." Very clever. You must have LEDs in both directions to charge and discharge the capacitor. The resistor is provided to take a heavy surge current through one of the strings of LEDs if the circuit is switched on when the mains is at a peak. This can be as high as 330mA if only 1 LED is used, so the value of this resistor must be adjusted if a small number of LEDs are used. The LEDs above detect peak current. The LEDs are turned on and off 50 times per second and this may create "flickering" or "strobing." To prevent this flicker, see the DC circuit below:

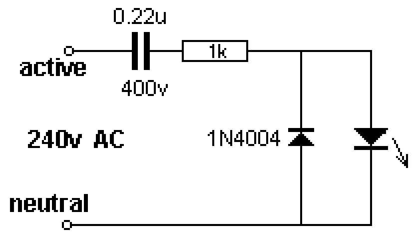
A 100n cap will deliver 7mA RMS or 10mA peak in full wave or 3.5mA RMS (10mA peak for half a cycle) in half-wave. (when only 1 LED is in each string)**.**

The current-capability of a capacitor needs more explanation. In the diagram on the left we see a capacitor feeding a full-wave power supply. This is exactly the same as the **LEDs on 240v** circuit above. Imagine the LOAD resistor is removed. Two of the diodes will face down and two will face up. This is exactly the same as the LEDs facing up and facing down in the circuit above. The only difference is the mid-point is joined. Since the voltage on the mid-point of one string is the same as the voltage at the mid-point of the other string, the link can be removed and the circuit will operate

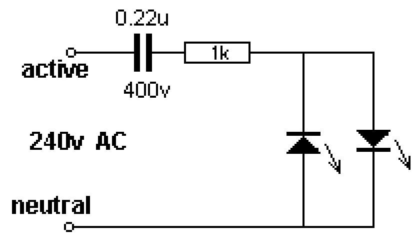
the same.
This means each 100n of capacitance will deliver 7mA RMS (10mA peak on each half-cycle).
In the half-wave supply, the capacitor delivers 3.5mA RMS (10mA peak on each half-cycle, but one half-cycle is lost in the diode) for each 100n to the load, and during the other half-cycle the 10mA peak is lost in the diode that discharges the capacitor.
You can use any LEDs and try to keep the total voltage-drop in each string equal. Each string is actually working on DC. It's not constant DC but varying DC. In fact is it zero current for 1/2 cycle then nothing until the voltage rises above the total characteristic voltage of all the LEDs, then a gradual increase in current over the remainder of the cycle, then a gradual decrease to zero over the falling portion of the cycle, then nothing for 1/2 cycle. Because the LEDs turn on and off, you may observe some flickering and that's why the two strings should be placed together.

SINGLE LED on 240v

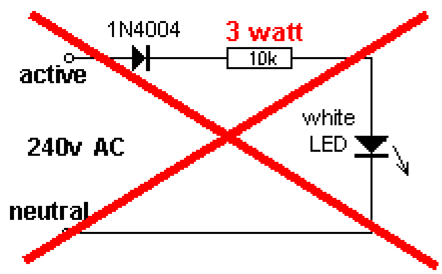
A single LED can be illuminated by using a 100n or 220n capacitor with a rating of 400v. These capacitors are called "X2" and are designed to be connected to the mains.



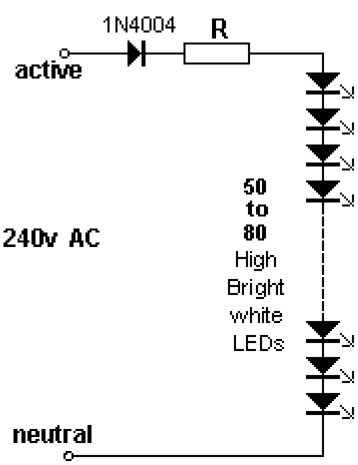
The LED will be 240v above earth if the active and neutral are swapped and this represents a shock of over 340v if anything is exposed. The power diode in the first diagram is designed to discharge the 0.22u during one half of the cycle so that the capacitor will charge during the other half-cycle and deliver energy to the LED. The 1k resistor limits the peak in-rush current when the circuit is first turned on and the mains happens to be at a peak.



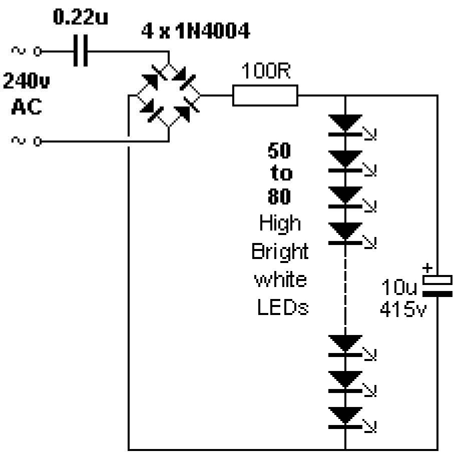
Two LEDs can be driven from the same circuit as one LED will be illuminated during the first half cycle and the other LED will be driven during the second half of the cycle.



LEDs can also be connected to the mains via a power diode and current-limiting resistor. But the wattage lost (dropped) in the resistor is about 2.5 watts and a 3 watt resistor will be needed to illuminate a 70mW white LED. This is an enormous waste of energy and a capacitor-fed supply shown above is the best solution.



When 50 to 80 white LEDs are connected in series, a resistor can be used. For 50 white LEDs, use a 4k7 2watt resistor to provide 10mA average current.
For 100 white LEDs, use a 2k2 1watt resistor to provide 10mA average current.
The circuit will not work with more than 95 LEDs as the characteristic voltage-drop across the combination will be more than the peak of the supply (340v).

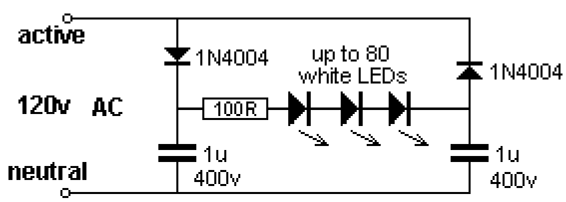


DC CONNECTION

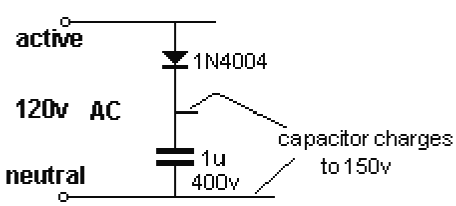
To prevent "flickering' or "strobing," the LEDs must be driven with DC. This requires a BRIDGE. (A bridge is used in this circuit however the secret to prevent flickering is the addition of the electrolytic and the circuit can be driven by a single diode in half-wave.)
The 0.22u will deliver 15mA when one LED is connected to the output. As additional LEDs are connected, the current gradually reduces to zero with 100 LEDs.
40 LEDs will be provided with:
345 - 145 = 200v = 200/345 x 15 = 8.6mA

LEDs on 120v

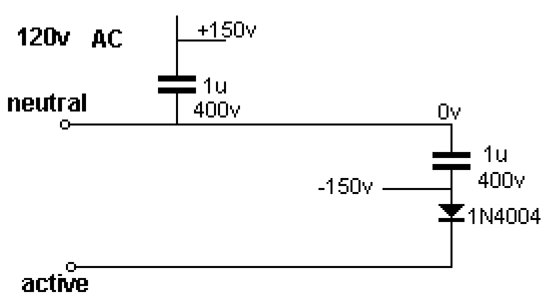
Here is a very clever CONSTANT-CURRENT voltage-doubling design. It produces up to 300v on a 120v supply and the current is 30mA. (see below for the reason why the current is 30mA for about 40 LEDs)
The amazing thing is, you can put any number of LEDs on the output, up to 80 white LEDs. When 80 LEDs are added, the current will reduce to only a few milliamps.



How does the circuit work?
We will explain how the circuit works in 3 steps.
Step 1: The 1u charges to the peak voltage of 150v when the active line is 150v higher than the neutral:



Step 2: When the active line is 150v LOWER than the neutral, the second capacitor charges as shown in the following diagram:



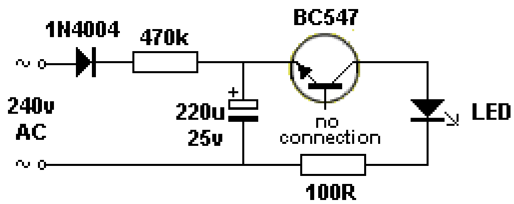
Step 3: The LEDs are connected to these capacitors and the resulting voltage is about 300v.
The characteristic voltage of about 3.6v for a white LED will reduce the voltage and that's why the 300v is only a theoretical maximum.
On each half-cycle, the energy from a 1u is fed to the string of LEDs and it will deliver an average of about 70mA when only 1 LED is in the chain.
This makes it a FULL WAVE capacitor-fed supply and because it is a capacitor-fed supply, it is a constant-current supply. The current will gradually decrease as the number of LEDs increase because the current though the capacitor depends on the voltage on each side of the capacitor. As the number of LEDs increase, the voltage on the LED-side of the capacitor increases, reducing the actual voltage across the capacitor.
The current will decrease by about 1mA for each added LED.

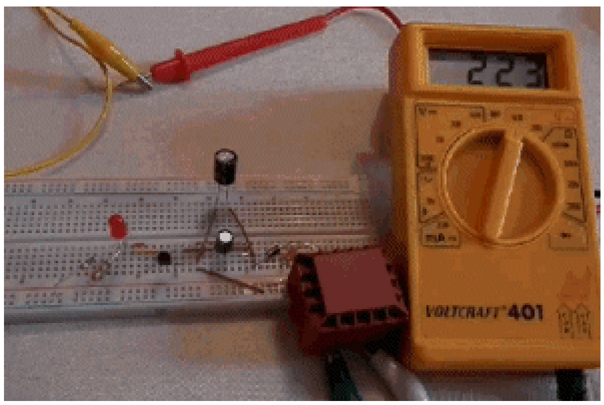
HOW TO VIEW THE "MAINS"

The mains is changing direction 50 or 60 times per second and this is called AC (Alternating Current). Instead of seeing the mains as "changing direction," it is more convenient to consider the Neutral as always at EARTH POTENTIAL and the Active is 150v higher than "earth" then 150v lower than earth.
Now you can understand the diagrams above.

FLASHING LED on 240v by Franz Bachler

This circuit flashes a single LED on 240v. The circuit will also work on 120v by reducing the 470k to 220k. The base of the transistor is **not** connected.





Flashing LED on 240v

HOW THE CIRCUIT WORKS

The NPN transistor is wired the wrong way round in the circuit, with a positive voltage on the emitter, and the base lead is left open. The voltage on the capacitor gradually rises to approximately 9v. At this point the transistor suddenly starts conducting and discharges the capacitor to deliver energy to the LED and produce a single flash. Each transistor behaves differently and it's worth trying a variety of transistors in this circuit.
When operated with an **inverted voltage** between the emitter and the collector, the transistor has a characteristic curve with a negative slope. The base-emitter junction exhibits an avalanche breakdown effect at approximately 9v. At this voltage the high electric field strength in the thin reverse-biased junction region causes the charge carriers to move so fast that they dislodge other charge-carriers from the crystal lattice. As a result the number of charge-carriers rises very quickly. This is the same as what happens in a 9v zener diode, but a zener diode has a positive internal resistance. There's another factor involved with an inverted transistor. Here the emitter and collector switch roles, but due to the essentially symmetrical structure, the transistor also operates in this inverted condition.

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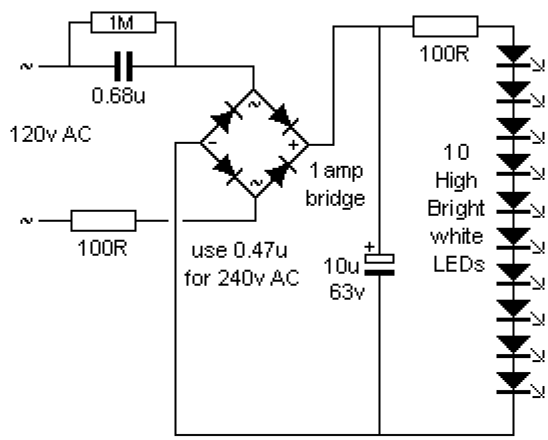
MAINS NIGHT LIGHT

The circuit illuminates a column of 10 white LEDs. The 10u prevents flicker and the 100R also reduces flicker (it allows the 10u to charge to a slightly higher value and this extra energy is delivered to the LEDs during each of the low portions of the AC cycle.)



This circuit is classified as a CONSTANT CURRENT GENERATOR or CONSTANT CURRENT CIRCUIT.
This means any component placed on the output of the circuit will pass 7mA if the capacitor is 100n on a 240v supply or 4.7 x 7mA = 33mA if the capacitor is 470n.
This also applies to a short-circuit on the output.
If no load is connected, the output voltage will be 230v x 1.4 = 320v and if the voltage across the load is 100v, the output will be reduced to about 20mA. If the output voltage is 200v, the current will be 10mA and if the output voltage is 300v, the current will be 0mA. In our case the output voltage will be about 35v and the current will be 30mA.
This means you cannot add LEDs endlessly. A time will come when they will simply not illuminate.

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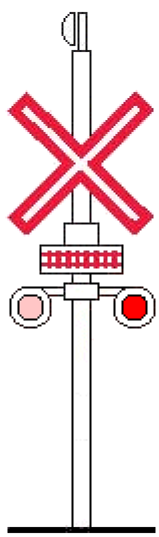
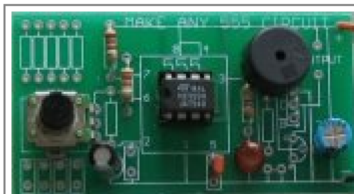
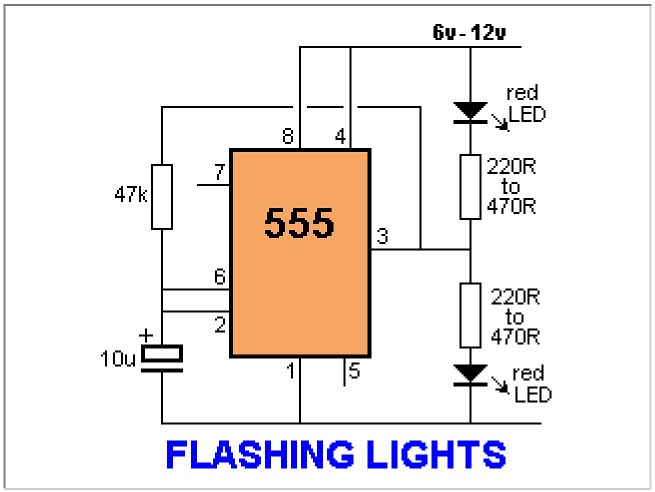
FLASHING RAILROAD LIGHTS

This circuit flashes two red LEDs for a model railway crossing:





This project can be constructed on our **MAKE ANY 555 PROJECT** printed circuit board.



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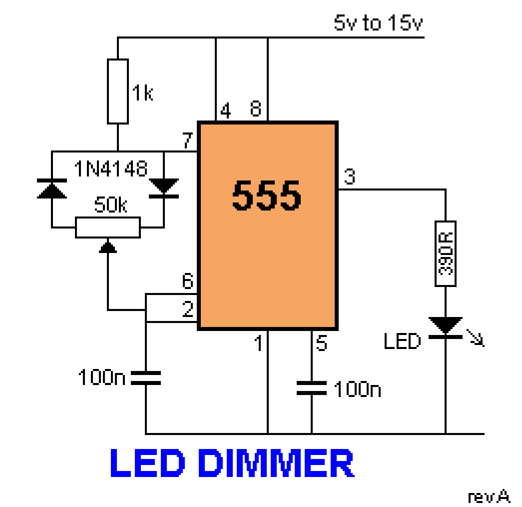
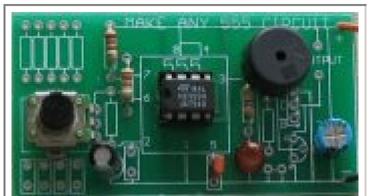
LED DIMMER

This circuit will adjust the brightness of one or more LEDs from 5% to 95%.





This project can be constructed on our **[MAKE ANY 555 PROJECT]** printed circuit board.

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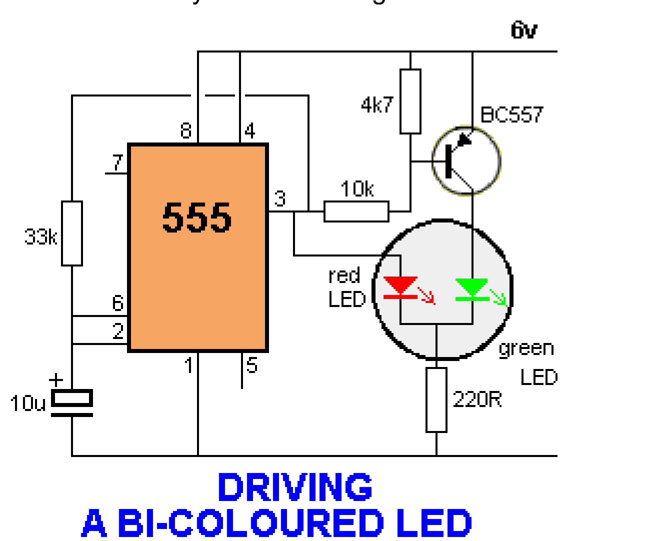
DRIVING A BI-COLOUR LED

Some 3-leaded LEDs produce red and green. This circuit alternately flashes a red/green bi-coloured LED:



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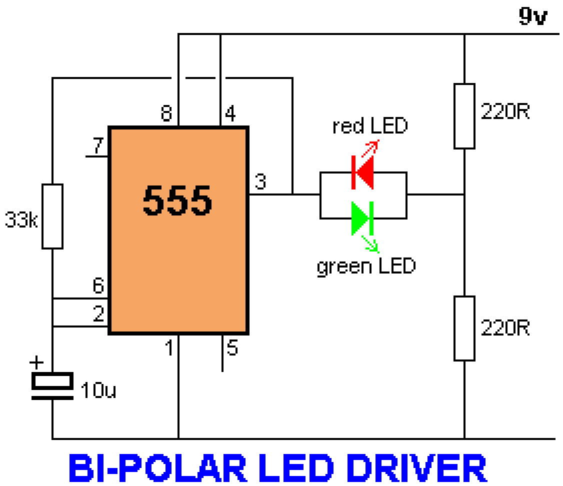
BI-POLAR LED DRIVER

Some 2-leaded LEDs produce red and green. These are called Bi-polar LEDs. This circuit alternately flashes a red/green bi-polar LED:



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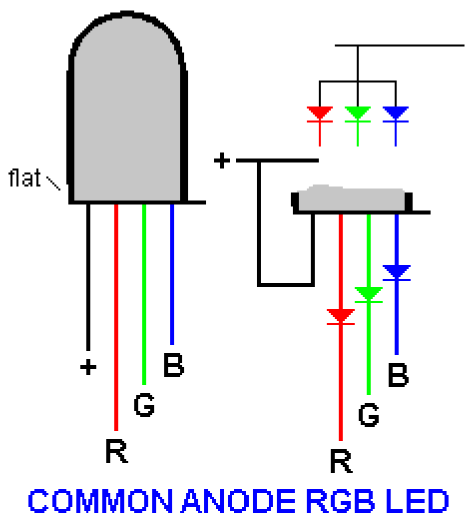
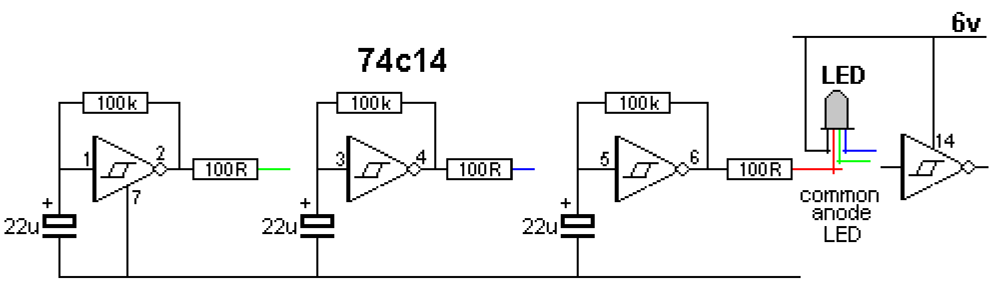
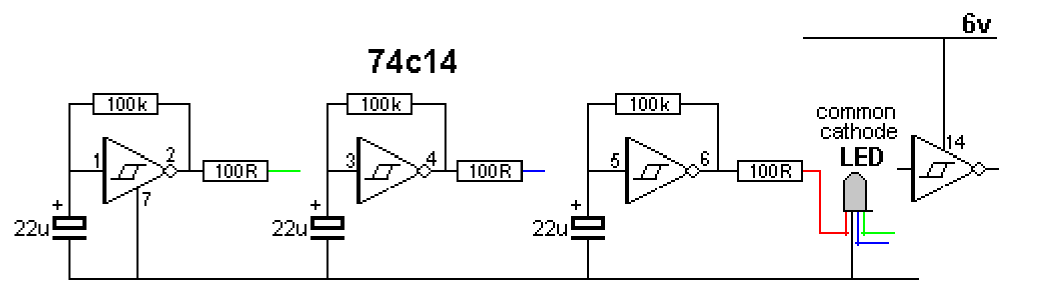
RGB LED DRIVER

This is a simple driver circuit that drives the 3 LEDs in an RGB LED to produce a number of interesting colours. Even though the component values are identical in the three oscillators, the slight difference in tolerances will create a random display of colours and it will take a while for the pattern to repeat.
The colours change abruptly from one colour to another as the circuit does not use Pulse Width Modulation to produce a gradual fading from one colour to another.
This LED is called COMMON ANODE. This has been done so it can be connected to transistors or other devices that "SINK."
The second circuit a common cathode LED.
Note the different pinout.







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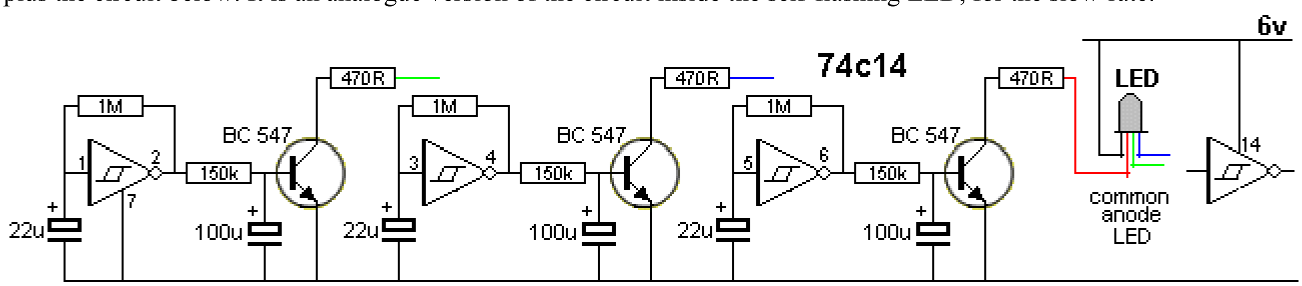
RGB LED FLASHER

This LED flashes at a fast rate then a slow rate. It only requires a current-limiting resistor of 100R for 4.5v to 6v supply or 470R for 7v to 12v supply.
This LED is available from: http://alan-parekh.vstore.ca/flashing-5000mcd-p-88.html for 80 cents plus postage.

There are two different types of RGB LEDs. The **RGB LED Driver** circuit above uses an RGB LED with 4 leads and has 3 coloured chips inside and NOTHING ELSE.
The LED described in the video has 2 leads and requires a dropper resistor so that about 20mA flows. The LED also contains a microcontroller producing PWM signals. If you cannot get the 2-leaded LED, you can use a 4-leaded LED plus the circuit below. It is an analogue version of the circuit inside the self-flashing LED, for the slow-rate:



As with everything Chinese, the self-flashing LED is too gimmicky.
It is better to produce your own colour-change via the circuit above. You can alter the rate by changing the value of the components and/or remove one or more of the 100u's. The circuit for a common cathode RGB LED is shown in the RGB LED Driver above.

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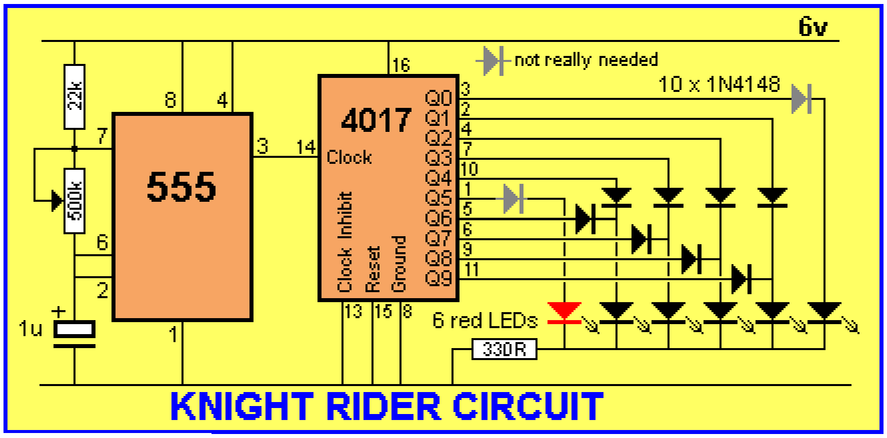
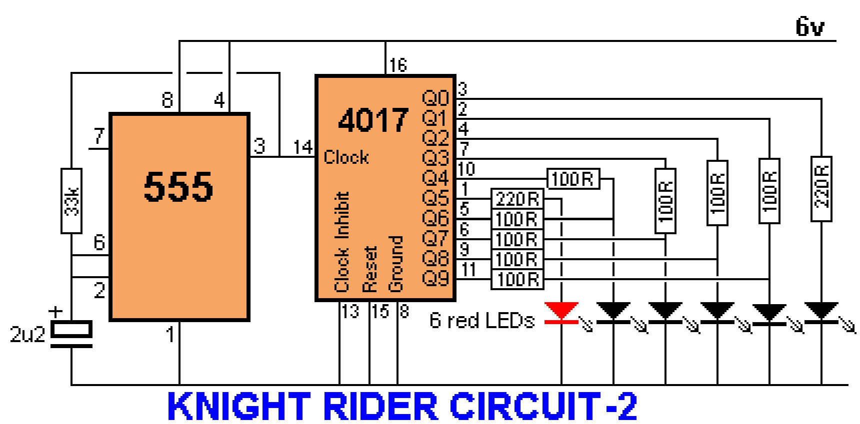
KNIGHT RIDER

In the **Knight Rider** circuit, the 555 is wired as an oscillator. It can be adjusted to give the desired speed for the display. The output of the 555 is directly connected to the input of a Johnson Counter (CD 4017). The input of the counter is called the CLOCK line.
The 10 outputs Q_0 to Q_9 become active, one at a time, on the rising edge of the waveform from the 555. Each output can deliver about 20mA but a LED should not be connected to the output without a current-limiting resistor (330R in the circuit above).
The first 6 outputs of the chip are connected directly to the 6 LEDs and these "move" across the display. The next 4 outputs move the effect in the opposite direction and the cycle repeats. The animation above shows how the effect appears on the display.
Using six 3mm LEDs, the display can be placed in the front of a model car to give a very realistic effect. The same outputs can be taken to driver transistors to produce a larger version of the display.



The **Knight Rider** circuit is available as a kit for less than $15.00 plus postage as **Kitt Scanner**.

Here is a simple Knight Rider circuit using resistors to drive the LEDs. This circuit consumes 22mA while only delivering 7mA to each LED. The outputs are "fighting" each other via the 100R resistors (except outputs Q0 and Q5).



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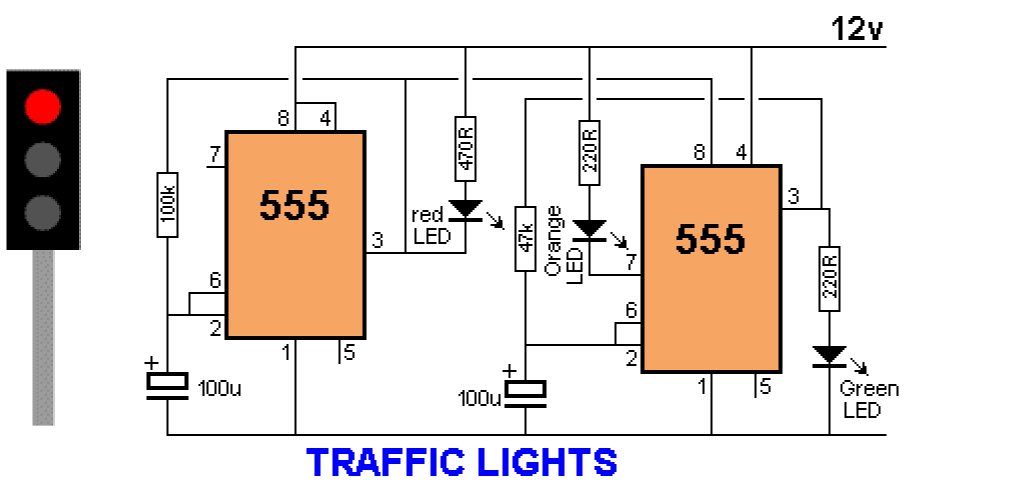
TRAFFIC LIGHTS

Here's a clever circuit using two 555's to produce a set of traffic lights for a model layout.
The animation shows the lighting sequence and this follows the Australian-standard. The red LED has an equal on-off period and when it is off, the first 555 delivers power to the second 555. This illuminates the Green LED and then the second 555 changes state to turn off the Green LED and turn on the Orange LED for a short period of time before the first 555 changes state to turn off the second 555 and turn on the red LED.
A supply voltage of 9v to 12v is needed because the second 555 receives a supply of about 2v less than rail. This circuit also shows how to connect LEDs high and low to a 555 and also turn off the 555 by controlling the supply to pin 8. Connecting the LEDs high and low to pin 3 will not work and since pin 7 is in phase with pin 3, it can be used to advantage in this design.



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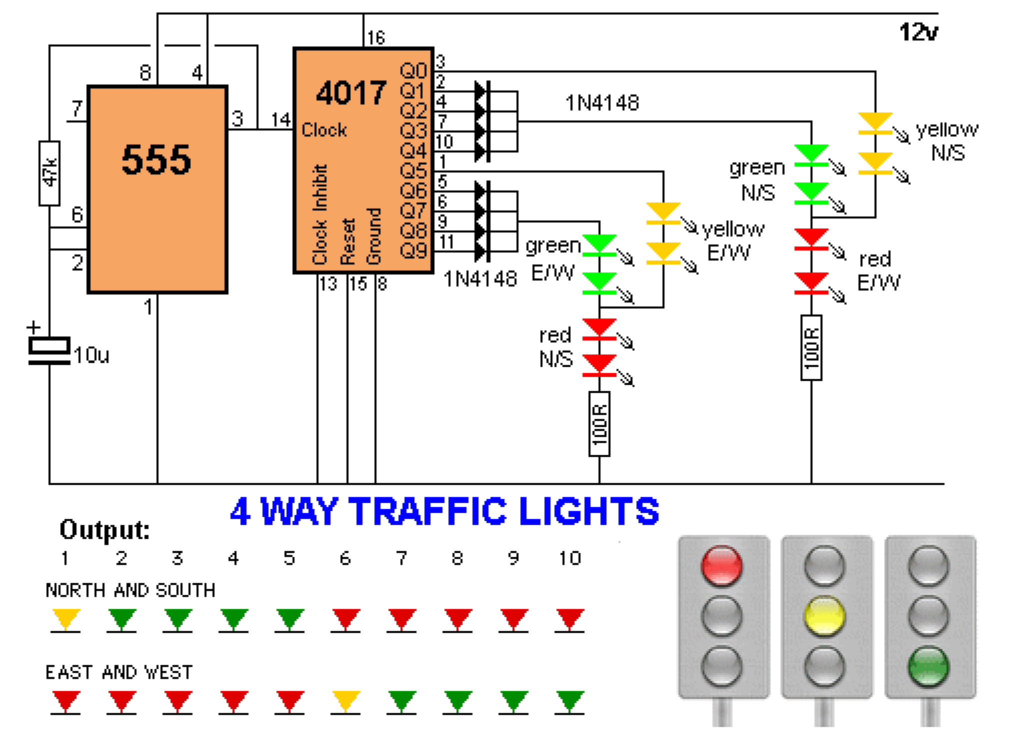
4 WAY TRAFFIC LIGHTS

This circuit produces traffic lights for a "4-way" intersection. The seemingly complex wiring to illuminate the lights is shown to be very simple.



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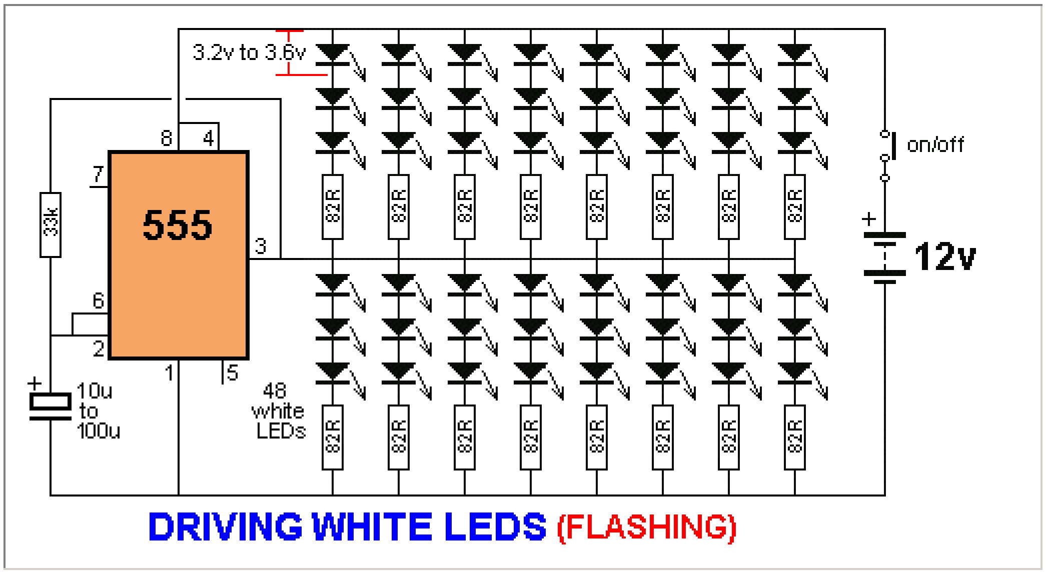
DRIVING MANY LEDS

The 555 is capable of sinking and sourcing up to 200mA, but it gets very hot when doing this on a 12v supply.

The following circuit shows the maximum number of white LEDs that can be realistically driven from a 555 and we have limited the total current to about 130mA as each LED is designed to pass about 17mA to 22mA maximum. A white LED drops a characteristic 3.2v to 3.6v and this means only 3 LEDs can be placed in series.



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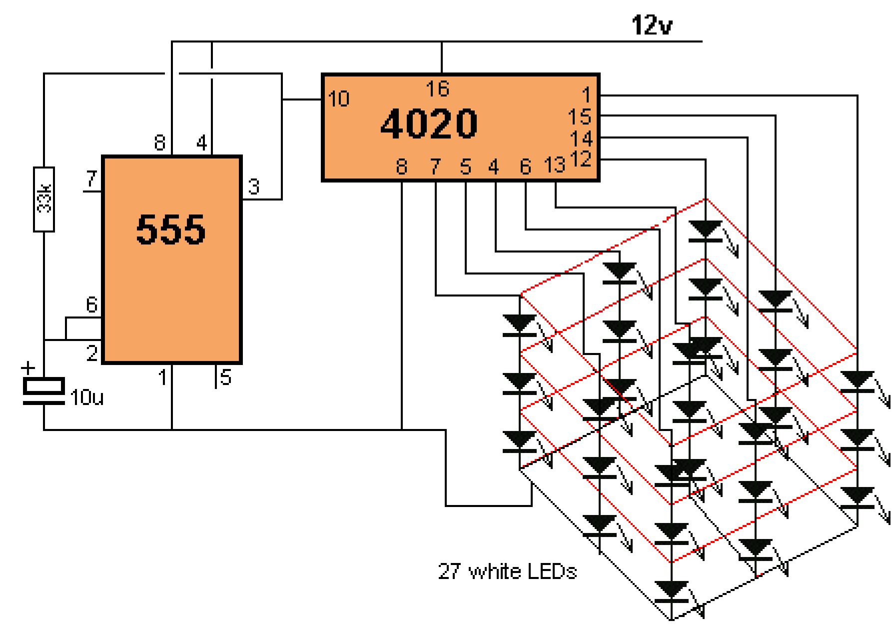
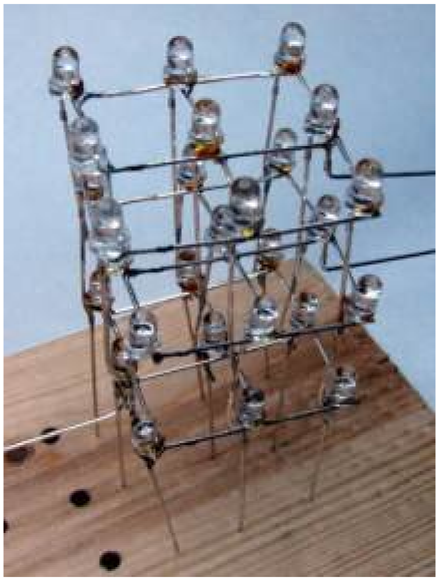
3x3x3 CUBE

This circuit drives a 3x3x3 cube consisting of 27 white LEDs. The 4020 IC is a 14 stage binary counter and we have used 9 outputs. Each output drives 3 white LEDs in series and we have omitted a dropper resistor as the chip can only deliver a maximum of 15mA per output. The 4020 produces 512 different patterns before the sequence repeats and you have to build the project to see the effects it produces on the 3D cube.





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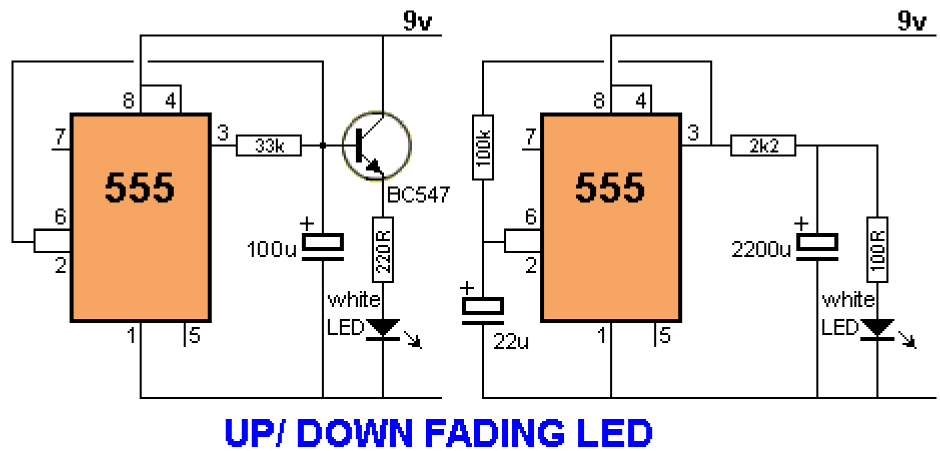
UP/DOWN FADING LED

These two circuits make a LED fade on and off. The first circuit charges a 100u and the transistor amplifies the current entering the 100u and delivers 100 times this value to the LED via the collector-emitter pins. The circuit needs 9v for operation since pin 2 of the 555 detects 2/3Vcc before changing the state of the output so we only have a maximum of 5.5v via a 220R resistor to illuminate the LED. The second circuit requires a very high value electrolytic to produce the same effect.



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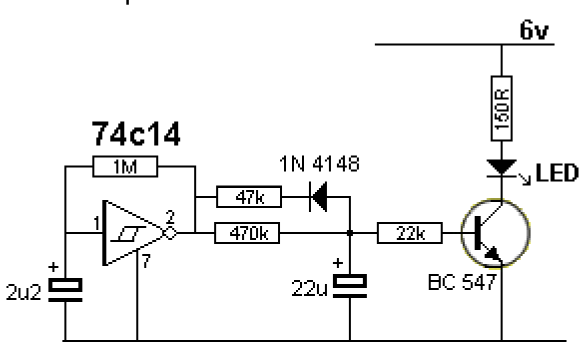
UP/DOWN FADING LED-2

The circuit fades the LED ON and OFF at an equal rate. The 470k charging and 47k discharging resistors have been chosen to create equal on and off times.



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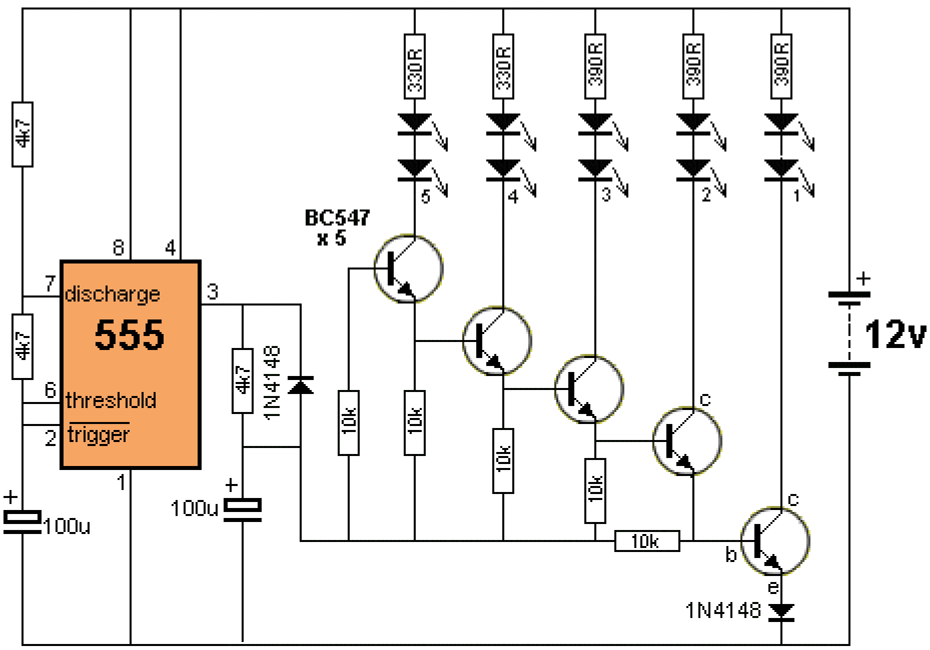
BIKE TURNING SIGNAL

This circuit can be used to indicate left and right turn on a motor-bike. Two identical circuits will be needed, one for left and one for right.



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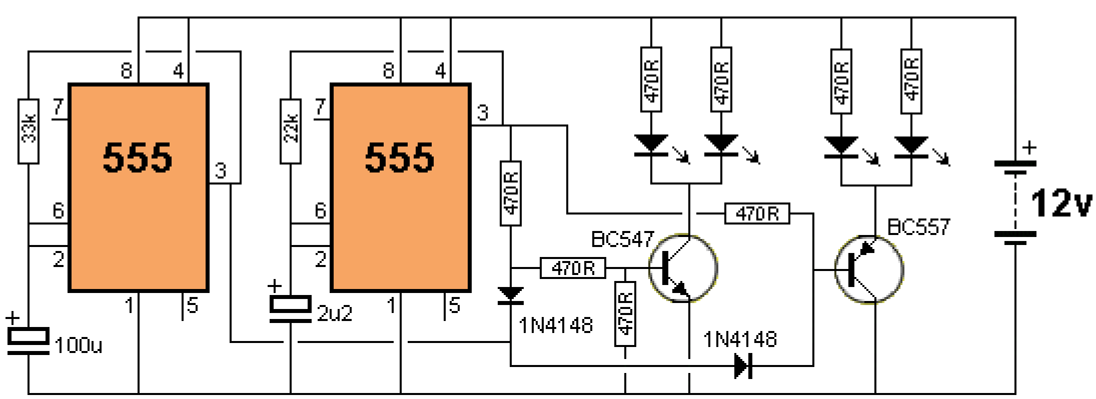
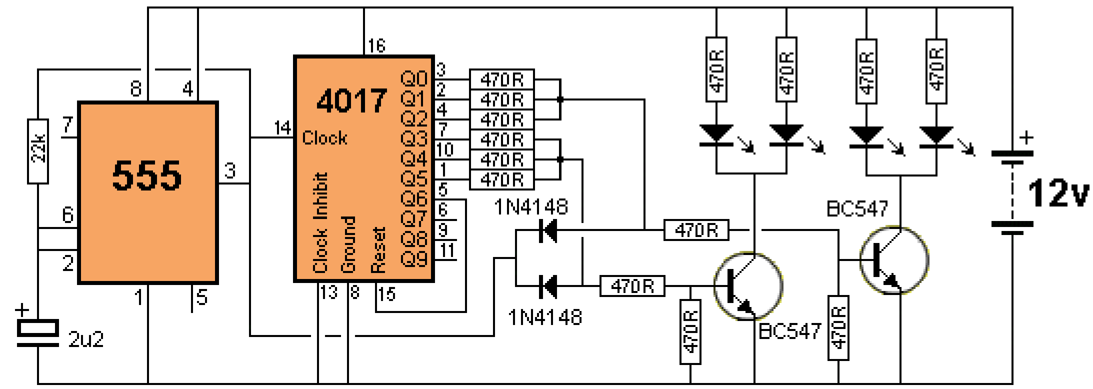
POLICE LIGHTS

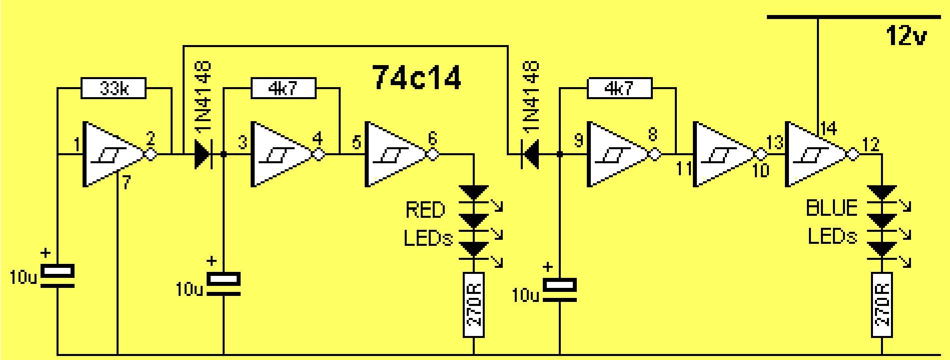
These three circuits flash the left LEDs 3 times then the right LEDs 3 times, then repeats. The only difference is the choice of chips.



POLICE LIGHTS



POLICE LIGHTS - 2



POLICE LIGHTS-3

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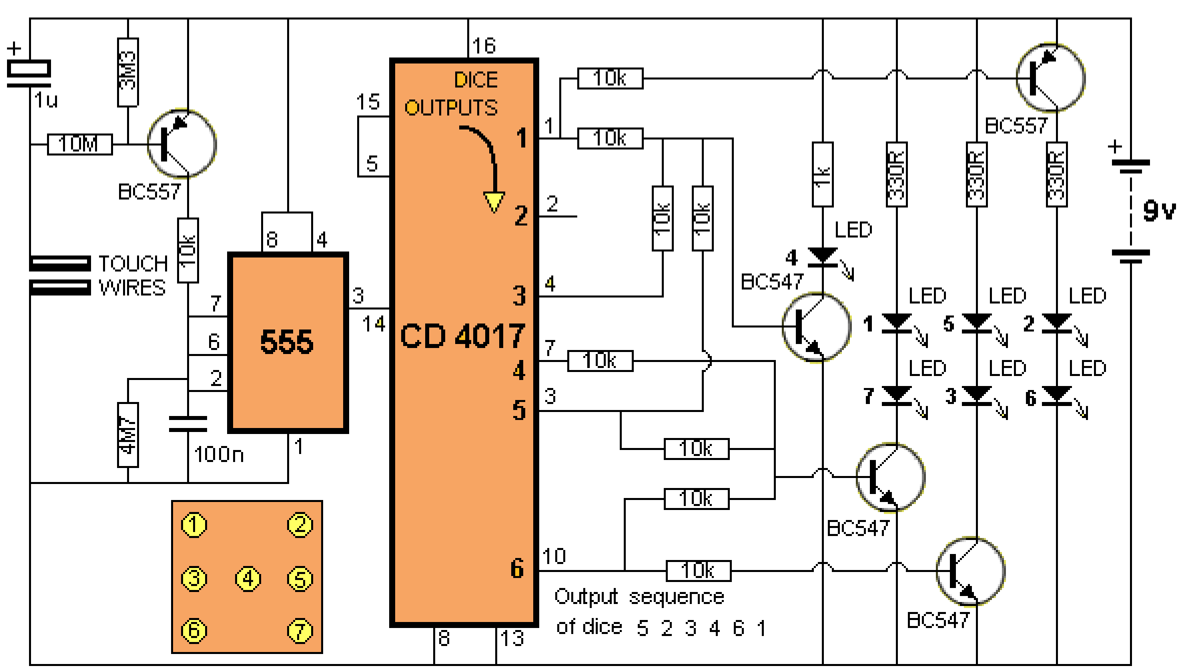
LED DICE with Slow Down

This circuit produces a random number from 1 to 6 on LEDs that are similar to the pips on the side of a dice. When the two TOUCH WIRES are touched with a finger, the LEDs flash very quickly and when the finger is removed, they gradually slow down and come to a stop. **LED Dice with Slow Down kit** is available from Talking Electronics.



The **LED Dice with Slow Down kit** is available for $16.00 plus $6.50 postage.
The kit includes the parts and PC board.

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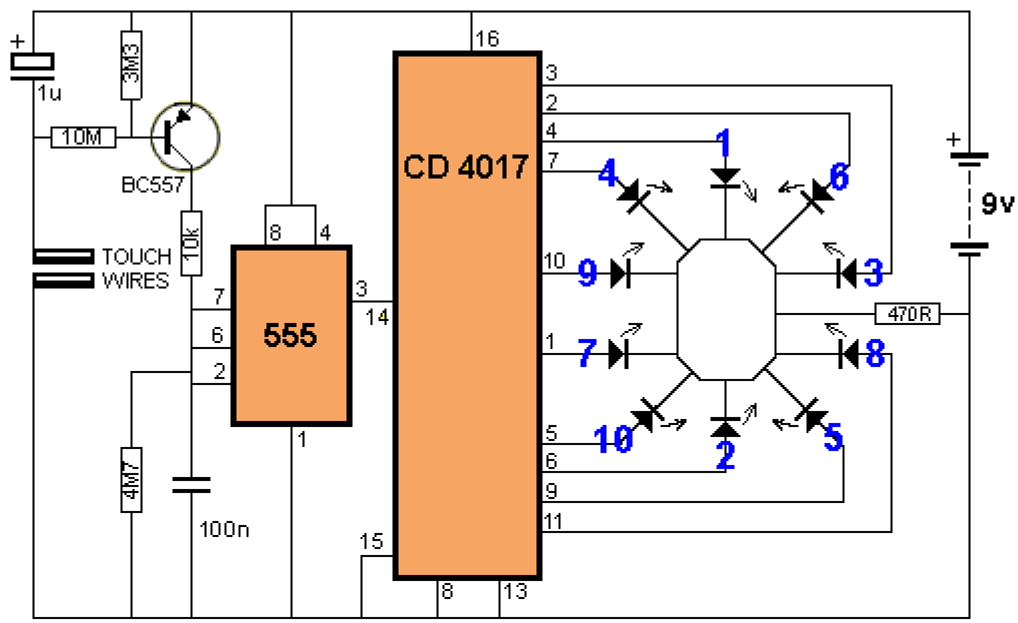
ROULETTE

This circuit creates a rotating LED that starts very fast when a finger touches the TOUCH WIRES. When the finger is removed, the rotation slows down and finally stops.



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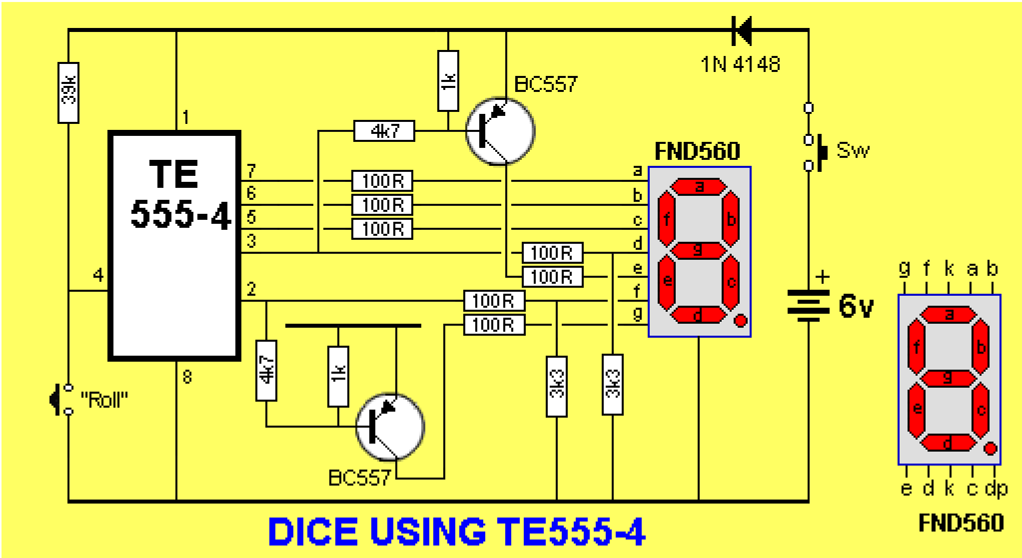
DICE TE555-4

This circuit uses the latest TE555-4 **DICE** chip from Talking Electronics. This 8-pin chip is available for $2.50 and drives a 7-Segment display. The circuit can be assembled on proto-type board. For more help on the list of components, email Colin Mitchell: talking@tpg.com.au



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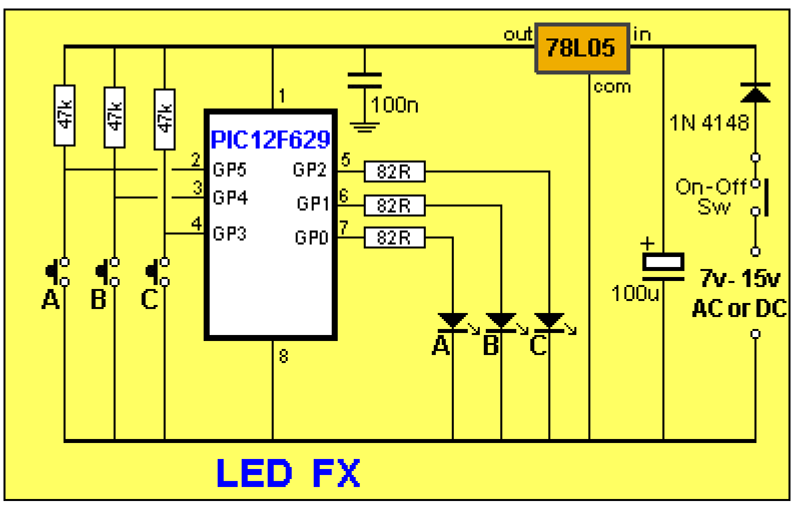
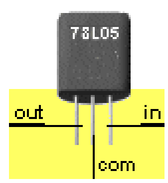
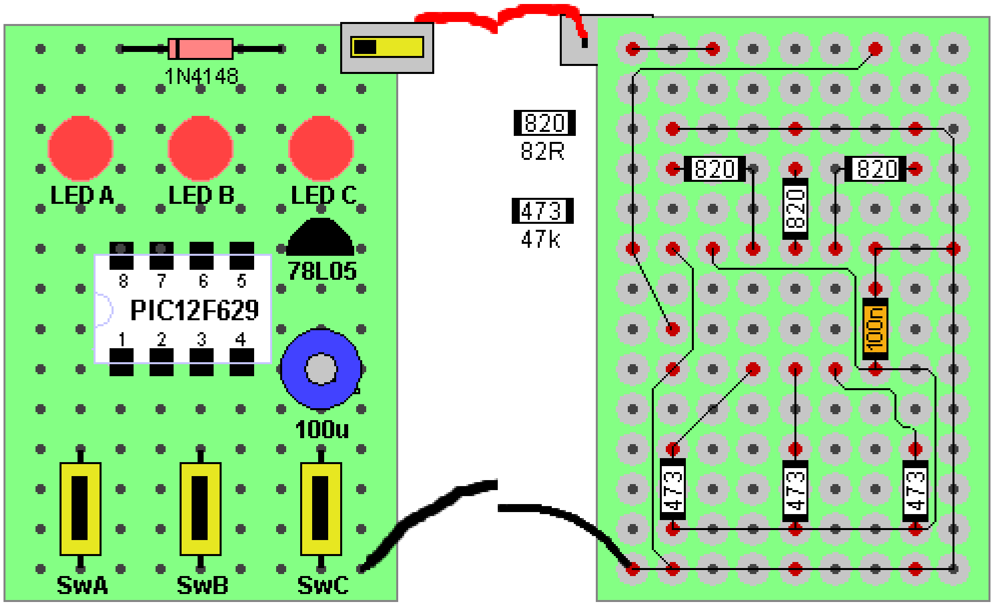
LED FX TE555-5

This circuit uses the latest [TE555-5](#) **LED FX** chip from Talking Electronics. This 8-pin chip is available for $2.50 and drives 3 LEDs. The circuit can be assembled on matrix board.
The circuit produces 12 different sequences including flashing, chasing, police lights and flicker. It also has a feature where you can create your own sequence and it will show each time the chip is turned on. The kit of components and matrix board can be purchased for $15.00 plus postage.
Email Colin Mitchell: talking@tpg.com.au for more details.







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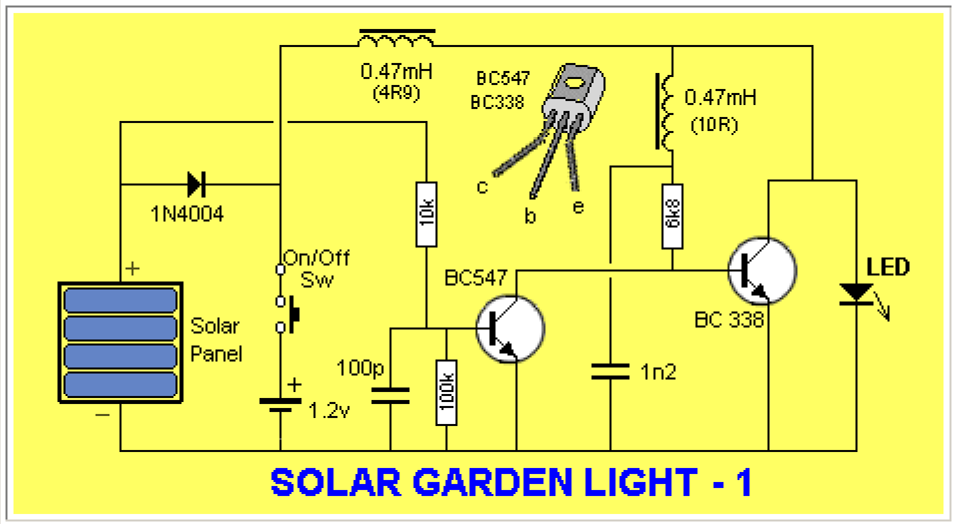
SOLAR GARDEN LIGHT

This is the circuit in a $2.00 Solar Garden Light.
The circuit illuminates a white LED from a 1.2v rechargeable cell.



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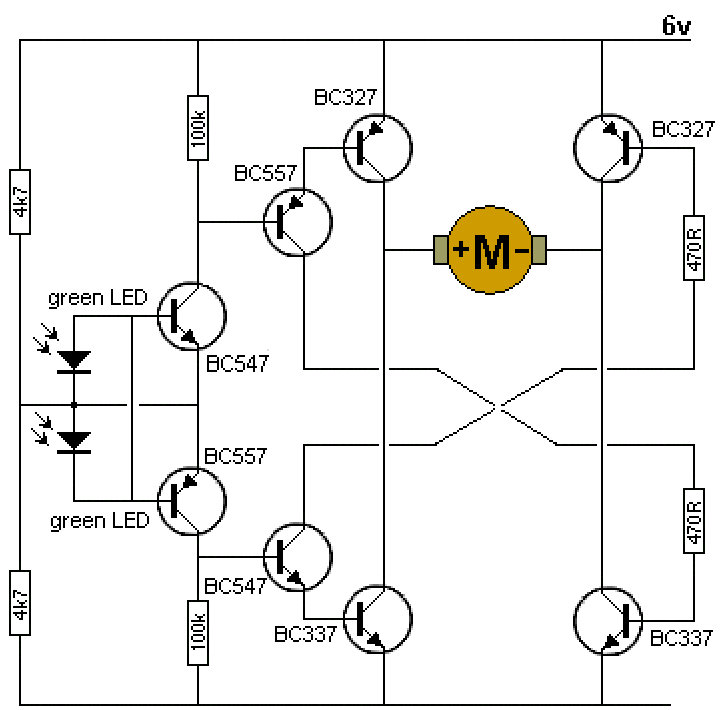
SOLAR TRACKER

This circuit is a SOLAR TRACKER. It uses green LEDs to detect the sun and an H-Bridge to drive the motor. A green LED produces nearly 1v but only a fraction of a milliamp when sunlight is detected by the crystal inside the LED and this creates an imbalance in the circuit to drive the motor either clockwise or anticlockwise. The circuit will deliver about 300mA to the motor. The circuit was designed by RedRok and kits for the **Solar Tracker** are available from: http://www.redrok.com/electron.htm#tracker This design is called: **LED5S5V Simplified LED low power tracker.**



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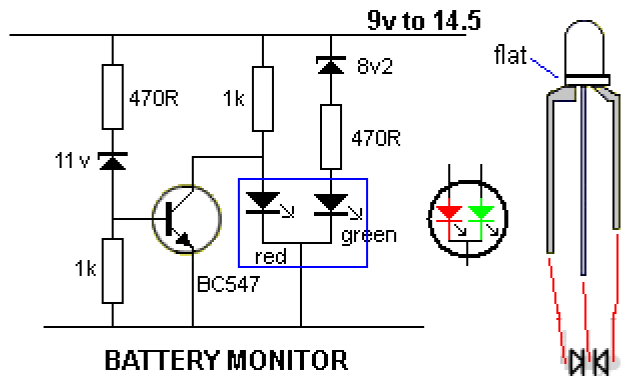
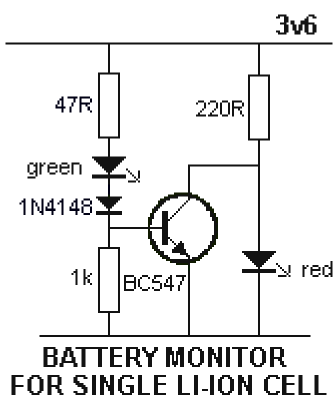
BATTERY MONITOR MkI

A very simple battery monitor can be made with a dual-colour LED and a few surrounding components. The LED produces orange when the red and green LEDs are illuminated.
The following circuit turns on the red LED below 10.5v
The orange LED illuminates between 10.5v and 11.6v.
The green LED illuminates above 11.6v



The following circuit monitors a single Li-ION cell. The green LED illuminates when the voltage is above 3.5v and the goes out when the voltage falls below 3.4v. The red LED then illuminates.



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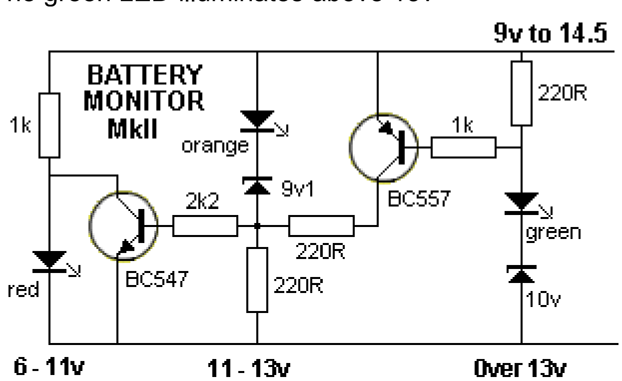
BATTERY MONITOR MkII

This battery monitor circuit uses 3 separate LEDs.
The red LED turns on from 6v to below 11v.
It turns off above 11v and
The orange LED illuminates between 11v and 13v.
It turns off above 13v and
The green LED illuminates above 13v



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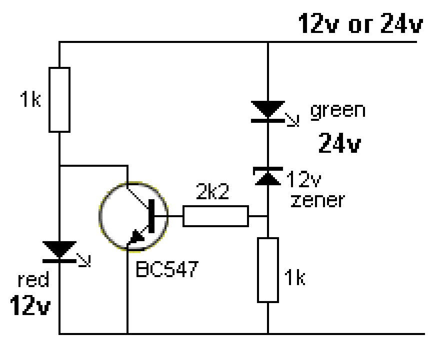
12v or 24v

This circuit turns on a red LED when 12v is present or the green LED when 24v is present:



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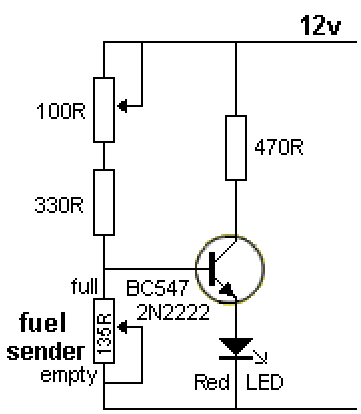
LOW FUEL INDICATOR

This circuit has been designed from a request by a reader. He wanted a low fuel indicator for his motorbike. The LED illuminates when the fuel gauge is 90 ohms. The tank is empty at 135 ohms and full at zero ohms. To adapt the circuit for an 80 ohm fuel sender, simply reduce the 330R to 150R. (The first thing you have to do is measure the resistance of the sender when the tank is amply.)



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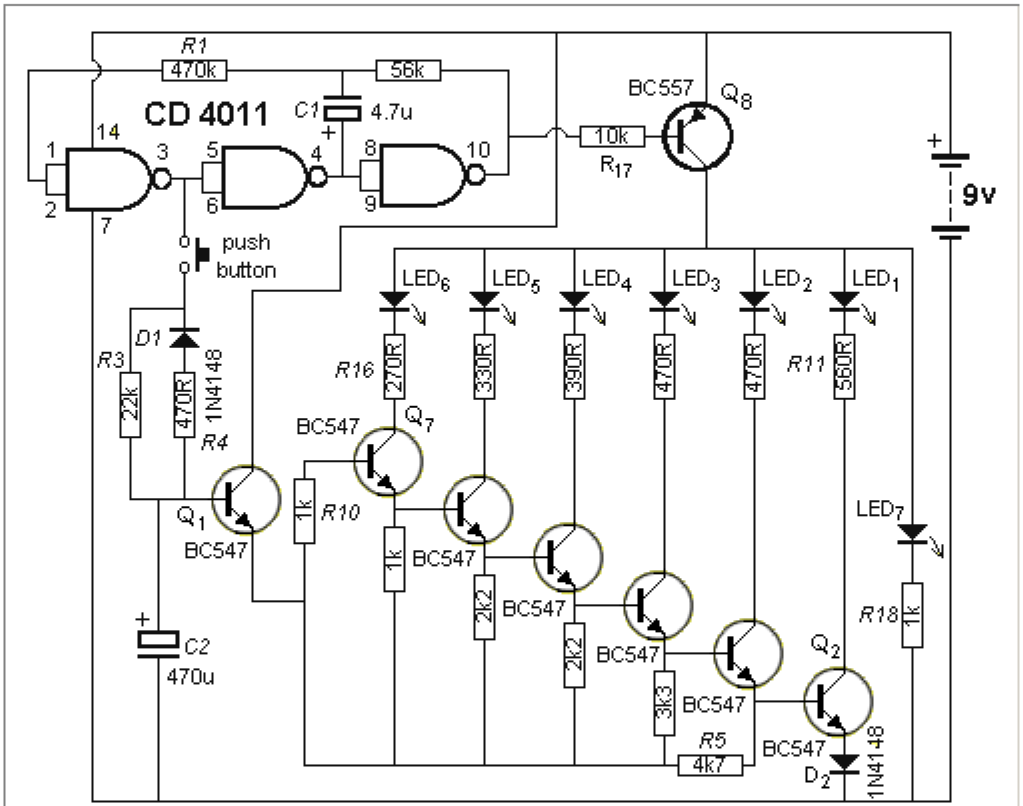
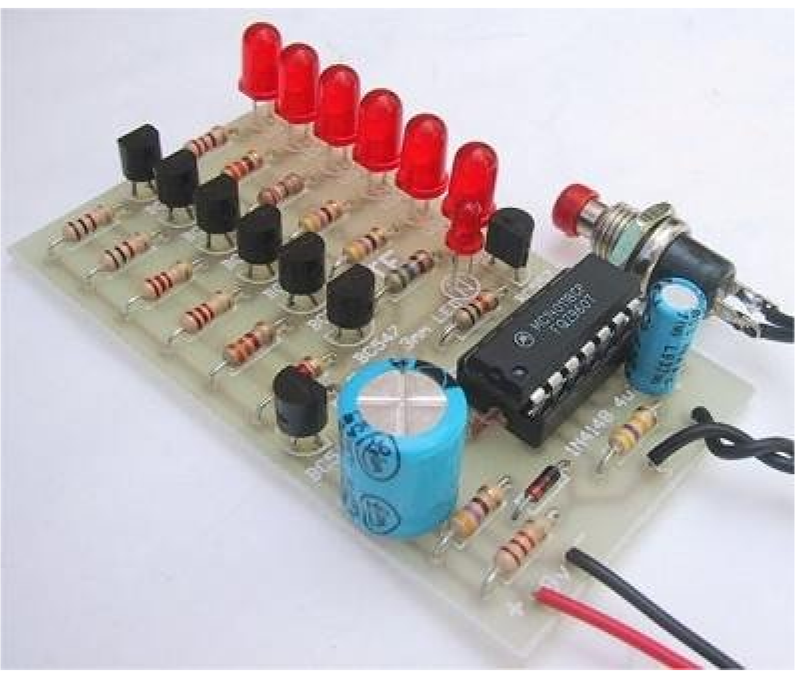
LED ZEPPELIN

This circuit is a game of skill. See full article: LED Zeppelin. The kit is available from talking electronics for $15.50 plus postage. Email **HERE** for details.
The game consists of six LEDs and an indicator LED that flashes at a rate of about 2 cycles per second. A push button is the "Operations Control" and by carefully pushing the button in synchronisation with the flashing LED, the row of LEDs will gradually light up.
But the slightest mistake will immediately extinguish one, two or three LEDs. The aim of the game is to illuminate the 6 LEDs with the least number of pushes.
We have sold thousands of these kits. It's a great challenge.





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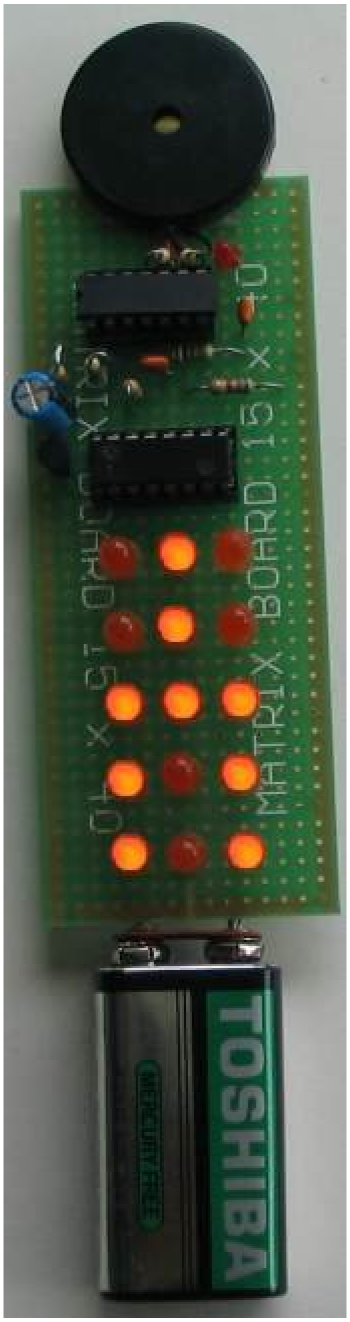
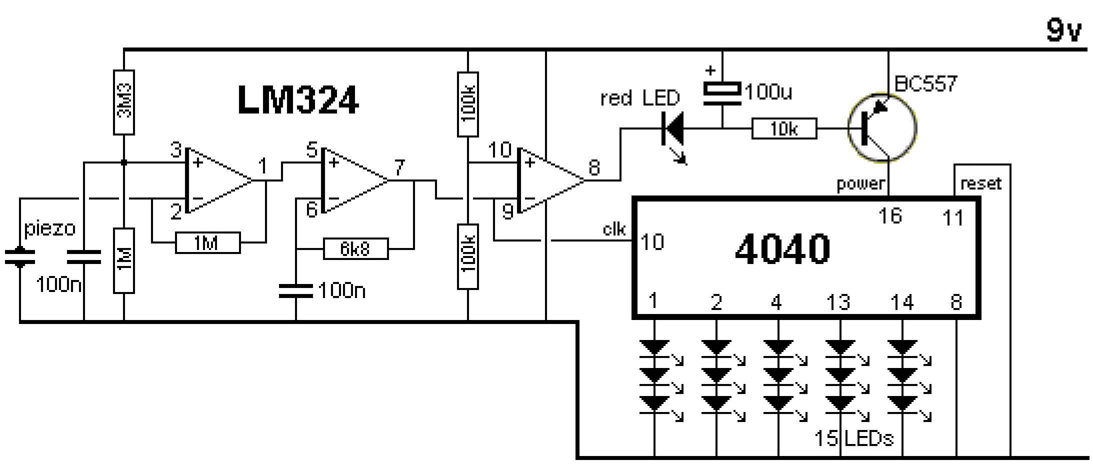
THE DOMINO EFFECT



Here's a project with an interesting name. The original design was bought over 40yearsa ago, before the introduction of the electret microphone. They used a crystal earpiece.
We have substituted it with a piezo diaphragm and used a quad op-amp to produce two building blocks. The first is a high-gain amplifier to take the few millivolts output of the piezo and amplify it sufficiently to drive the input of a counter chip. This requires a waveform of at least 6v for a 9v supply and we need a gain of about 600.
The other building block is simply a buffer that takes the high-amplitude waveform and delivers the negative excursions to a reservoir capacitor (100u electrolytic). The charge on this capacitor turns on a BC557 transistor and this effectively takes the power pin of the counter-chip to the positive rail via the collector lead.
The chip has internal current limiting and some of the outputs are taken to sets of three LEDs.
The chip is actually a counter or divider and the frequency picked up by the piezo is divided by 128 and delivered to one output and divided by over 8,000 by the highest-division output to three more LEDs The other lines have lower divisions.
This creates a very impressive effect as the LEDs are connected to produce a balanced display that changes according to the beat of the music.
The voltage on the three amplifiers is determined by the 3M3 and 1M voltage-divider on the first op-amp. It produces about 2v. This makes the output go HIGH and it takes pin 2 with it until this pin see a few millivolts above pin3. At this point the output stops rising.
Any waveform (voltage) produced by the piezo that is lower than the voltage on pin 3 will make the output go HIGH and this is how we get a large waveform.
This signal is passed to the second op-amp and because the voltage on pin 6 is delayed slightly by the 100n capacitor, is also produces a gain.
When no signal is picked up by the piezo, pin 7 is approx 2v and pin 10 is about 4.5v. Because pin 9 is lower than pin 10, the output pin 8 is about 7.7v (1.3v below the supply rail) as this is as high as the output will go - it does not go full rail-to-rail.
The LED connected to the output removes 1.7v, plus 0.6v between base and emitter and this means the transistor is not turned on.
Any colour LEDs can be used and a mixture will give a different effect.



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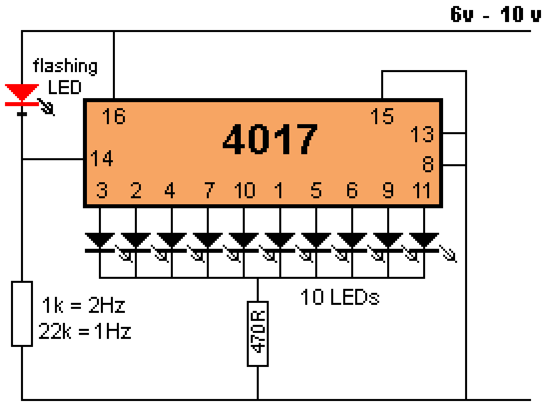
10 LED CHASER
Here's an interesting circuit that creates a clock pulse for a 4017 from a flashing LED. The flashing

LED takes almost no current between flashes and thus the clock line is low via the 1k to 22k resistor. When the LED flashes, the voltage on the clock line is about 2v -3v below the rail voltage (depending on the value of the resistor) and this is sufficient for the chip to see a HIGH.



(circuit designed on 9-10-2010)

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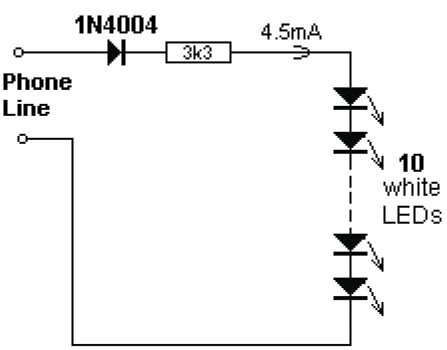
Emergency PHONE-LINE LIGHT

Here's a project that uses the phone line to illuminate a set of white LEDs.
The circuit delivers a current of 4.5mA as any current above 10mA will be detected by the exchange as the hand-set off the hook.
Be warned: This type of circuit is not allowed as it uses the energy from the phone line (called "leeching") and may prevent the phone from working.



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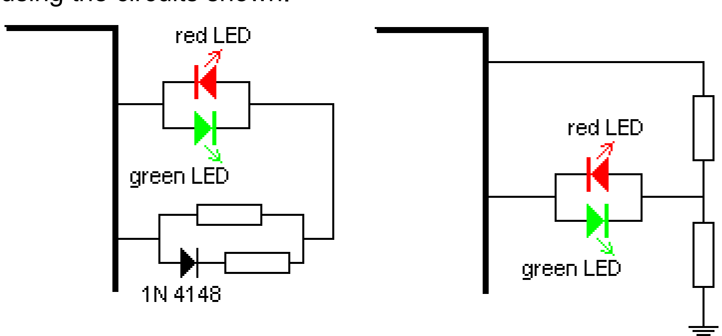
EQUAL BRIGHTNESS

A 2-leaded dual colour LED can be connected to the outputs of a microcontroller and the brightness can be equalized by using the circuits shown.



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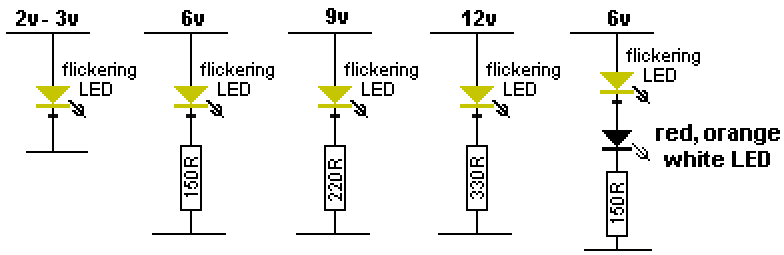
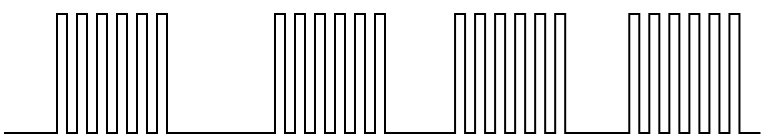
FLICKERING LED

A Flickering LED is available from eBay and some electronics shops.
It can be connected to a supply from 2v to 6v and needs an external resistor when the supply is above 3v. The LED has an internal circuit to create the flickering effect and limit the current.
We suggest adding a 150R resistor when the supply is above 3v and up to 6v. Above 6v, the current-limit resistor should be increased to 220R for 9v and 330R for 12v.
You can connect the flickering LED to an ordinary LED and both will flicker. Here are some arrangements:



The Pulse-Width Modulation to activate the flickering can be observed on an oscilloscope by connecting the probe across the LED. It is a very complex waveform. It is approx 1v in amplitude and approx 15 x 1kHz pulses to create each portion of the on-time, something like this:
The pulses vary in width to create a brighter illumination.



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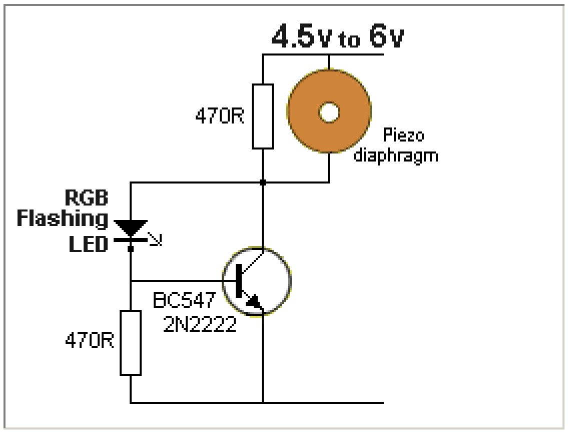
RGB FLASHING LED
There are many different flickering and flashing LEDs on the market via eBay.
They contain a microscopic microcontroller chip and current limiting resistor. Many of them work on a voltage from 3v to 6v and you can hear the oscillator turning ON and OFF to produce the different effects by building the following circuit:



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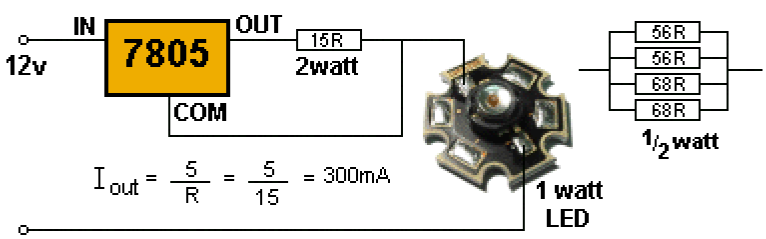
CONSTANT-CURRENT 7805 DRIVES 1 WATT LED

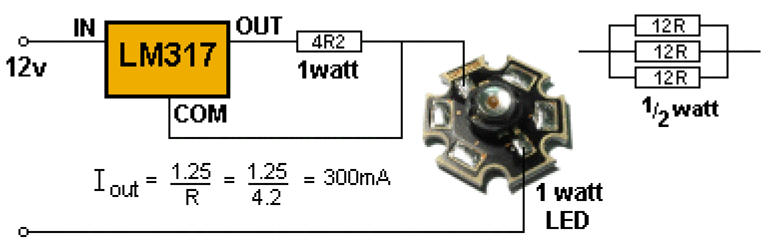
The circuit can be reduced to 2 components:



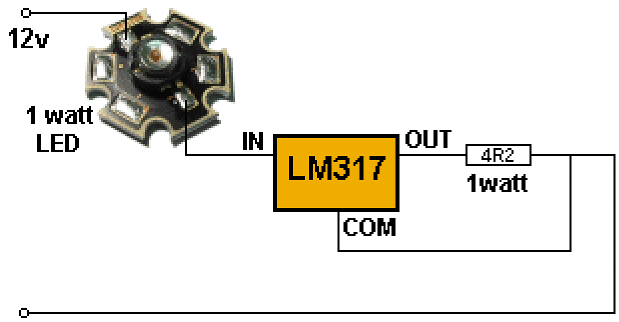
The 7805 can be converted into a content-current device by connecting a resistor as shown above.
We will take the operation of the circuit in slow-motion to see how it works.
As the 12v rises from 0v, the 7805 starts to work and when the input voltage is 4v, the output is 1v as a minimum of 3v is lost across the 7805. The voltage rises further and when the output is 5v, current flows through the 15R resistor and illuminates the LED. The LED starts to illuminate at 3.4v and the voltage across the 15R at the moment is 1.6v and the output current will be 100mA. The input voltage keeps rising and now the output voltage is 7v. The current through the LED increases and now the voltage across the LED is 3.5v. The voltage across the 15R is 3.5v and the current is 230mA. The input voltage keeps rising and the output voltage is now 8.6v The current through the LED increases and the voltage across the LED is now 3.6v. The voltage across the 15R is 5v and the current is 330mA. The input voltage keeps rising but a detector inside the 7805 detects the output voltage is exactly 5v above the common and the output voltage does not rise any more. The input voltage can rise above 13v, 14v . . . . 25v or more but the output voltage will not rise.
If the output voltage rises, more current will be delivered to the LED and the voltage across the 15R will increase. The 7805 will not allow this to happen.
The LED will have 3.6v across it. The 15R will have 5v across it and the output will be 8.6v. The input voltage will have to be at least 12.6v for the 7805 to operate.

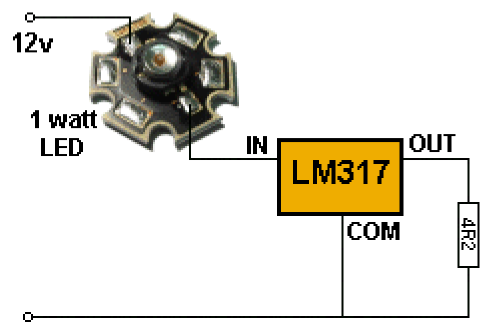
USING LM317

The 3-Terminal Regulator can be LM317. This is similar to 7805 except the voltage between the COM and OUT is 1.25v instead of 5v. When using an LM317 regulator, less wattage will be lost in the resistor and more heat will be generated via the regulator, when compared with a a 7805 however the total wattage lost will b the same in both cases.



Since the LED and regulator are in series, the LED can be placed before the regulator:





Driving a single 1watt LED from 12v is very inefficient.
The voltage across the LED will be about 3.6v. The remaining 8.4v must be dropped across the LM317 and 4R2 resistor. The 4R2 must have 1.25v across it for the LM317 to operate and the LM317 has 7.15v across it.
The minimum voltage across a LM317 is about 3v and this voltage is required to operate the circuitry inside the regulator.
This means two 1watt LEDs can be placed on a 12v supply and the regulator will run cooler while the circuit will produce twice the light-output for no additional current.

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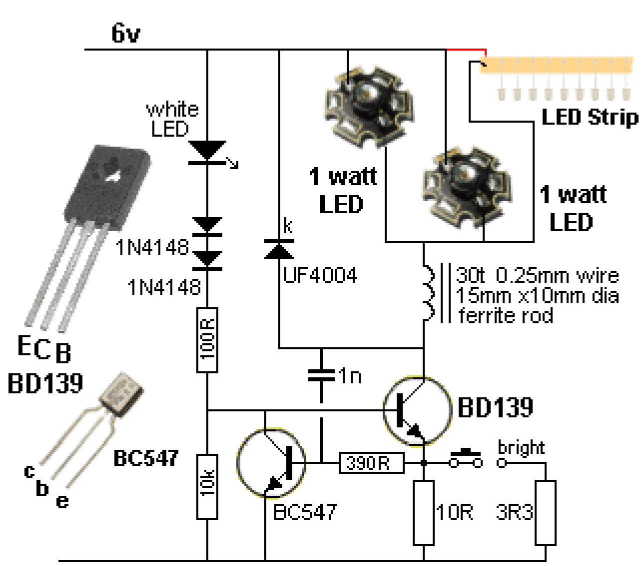
1-WATT LED - very good design



Circuit takes 70mA on LOW brightness and 120mA on HIGH Brightness

This circuit has been specially designed for a 6v rechargeable battery or 5 x 1.2v NiCad cells. **Do not use any other voltage.**
It has many features:
The pulse-operation to the two 1-watt LEDs delivers a high current for a short period of time and this improves the brightness.
The circuit can drive two 1-watt LEDs with extremely good brightness and this makes it more efficient than any other design.
The circuit is a two-transistor high-frequency oscillator and it works like this:
The BD139 is turned ON via the base, through the white LED and two signal diodes and it amplifies this current to appear though the collector-emitter circuit. This current flows though the 1-watt LED to turn it ON and also through the 30-turn winding of the inductor. At the same time the current through the 10R creates a voltage-drop and when this voltage rises to 0.65v, the BC547 transistor starts to turn ON. This robs the base of the BD139 of "turn-on voltage" and the current through the inductor ceases to be expanding flux, but stationary flux.
The 1n capacitor was initially pushing against the voltage-rise on the base of the BC547 but it now has a reverse-effect of allowing the BC547 to turn ON.
This turns off the BD139 a little more and the current through the inductor reduces.

This creates a collapsing flux that produces a voltage across the coil in the opposite direction. This voltage passes via the 1n to turn the BC547 ON and the BD139 is fully turned OFF.
The inductor effectively becomes a miniature battery with negative on the lower LED and positive at the anode of the Ultra Fast diode. The voltage produced by the inductor flows through the UF diode and both 1-watt LEDs to give them a spike of high current. The circuit operates at approx 500kHz and this will depend on the inductance of the inductor.
The circuit has about 85% efficiency due to the absence of a current-limiting resistor, and shuts off at 4v, thus preventing deep-discharge of the rechargeable cells or 6v battery.
The clever part of the circuit is the white LED and two diodes. These form a zener reference to turn the circuit off at 4v. The 10k resistor helps too.
The circuit takes 70mA on low brightness and 120mA on HIGH brightness via the brightness-switch.
The LEDs actually get 200mA pulses of current and this produces the high brightness.

The Inductor

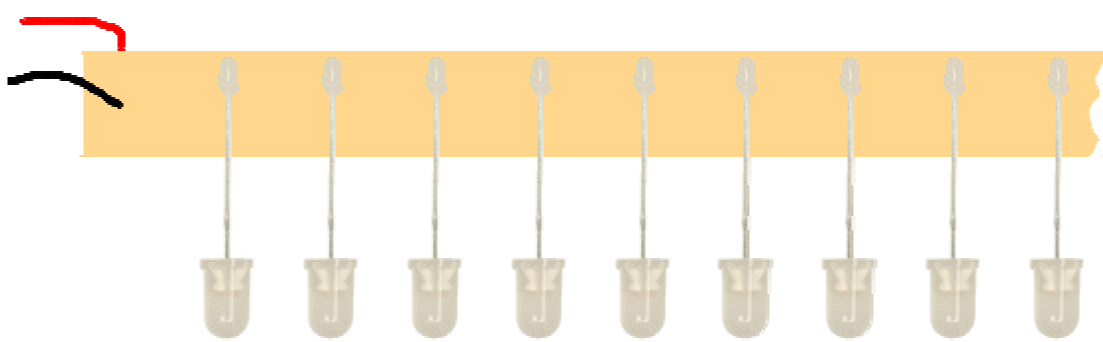
The coil or inductor is not critical. You can use a broken antenna rod from an AM radio (or a flat antenna slab) or an inductor from a computer power supply. Look for an inductor with a few turns of thick wire (at least 30) and you won't have to re-wind it.
Here are two inductors from surplus outlets:
http://www.goldmine-elec-products.com/prodinfo.asp?number=G16521B
- 50 cents
http://www.allelectronics.com/make-a-store/item/CR-345/345-UH-TOROIDAL-INDUCTOR/1.html - 40cents

Here are the surplus inductors:

The cost of surplus is from 10 cents to 50 cents, but you are sure to find something from a computer power supply.
Pick an inductor that is about 6mm to 10mm diameter and 10mm to 15mm high. Larger inductor will not do any damage. They simply have more ferrite material to store the energy and will not be saturated. It is the circuit that delivers the energy to the inductor and then the inductor releases it to the LEDs via the high speed diode.

IMPROVEMENT

By using the following idea, the current reduces to 90mA and 70mA and the illumination over a workbench is much better than a single high-power LED. It is much brighter and much nicer to work under.
Connect fifteen 5mm LEDs in parallel (I used 20,000mcd LEDs) by soldering them to a double-sided strip of PC board, 10mm wide and 300mm long. Space them at about 20mm. I know you shouldn't connect LEDs in parallel, but the concept works very well in this case. If some of the LEDs have a characteristic high voltage and do not illuminate very brightly, simply replace them and use them later for another strip.
You can replace one or both the 1-watt LEDs with a LED Strip, as shown below:



No current-limit resistor. . . why isn't the LED damaged?

Here's why the LED isn't damaged:
When the BD139 transistor turns ON, current flows through the LEDs and the inductor. This current gradually increases due to the gradual turning-on of the transistor and it is also increasing through the inductor. The

inductor also has an effect of slowing-down the "in-rush" of current due to the expanding flux cutting the turns of the coil, so there is a "double-effect" on avoiding a high initial current. That's why there is little chance of damaging the LEDs.
When it reaches 65mA, it produces a voltage of .065 x 10 = 650mV across the 10R resistor, but the 1n is pushing against this increase and it may have to rise to 150mA to turn on the BC547. LEDs can withstand 4 times the normal current for very short periods of time and that's what happens in this case. The BD139 is then turned off by the voltage produced by the inductor due to the collapsing magnetic flux and a spike of high current is passed to the LEDs via the high speed diode. During each cycle, the LEDs receive two pulses of high current and this produces a very high brightness with the least amount of energy from the supply. All the components run "cold" and even the 1-watt LEDs are hardly warm.

Charging and Discharging

This project is designed to use all your old NiCad cells and mobile phone batteries.
It doesn't matter if you mix up sizes and type as the circuit takes a low current and shuts off when the voltage is approx 4v for a 6v pack.
If you mix up 600mA-Hr cells with 1650mA-Hr, 2,000mA-Hr and 2,400mA-Hr, the lowest capacity cell will determine the operating time.
The capacity of a cells is called "C."
Normally, a cell is charged at the 14 hour-rate.
The charging current is 10% of the capacity. For a 600mA-Hr cell, this is 60mA. In 10 hours it will be fully charged, but charging is not 100% efficient and so we allow another 2 to 4 hours.
For a 2,400mA-Hr cell, it is 240mA. If you charge them faster than 14-hr rate, they will get HOT and if they get very hot, they may leak or even explode. But this project is designed to be charged via a solar panel using 100mA to 200mA cells, so nothing will be damaged.
Ideally a battery is discharged at C/10 rate. This means the battery will last 10 hours and for a 600mA-Hr cell, this is 60mA. If you discharge it at the "C-rate," it will theoretically last 1 hour and the current will be 600mA. But at 600mA, the cells may only last 45 minutes. If you discharge is at C/5 rate, it will last 5 hours.
Our project takes 120mA so no cell will be too-stressed. A 600mA-Hr cell will last about 4-5 hours, while the other cells will last up to 24 hours. Try to keep the capacity of each cell in a "battery-pack" equal.

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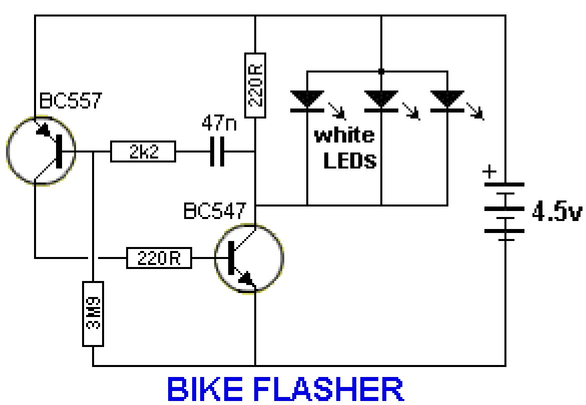
BIKE FLASHER

This circuit will flash a white LED (or 2,3 4 LEDs in parallel) at 2.7Hz, suitable for the rear light on a bike.



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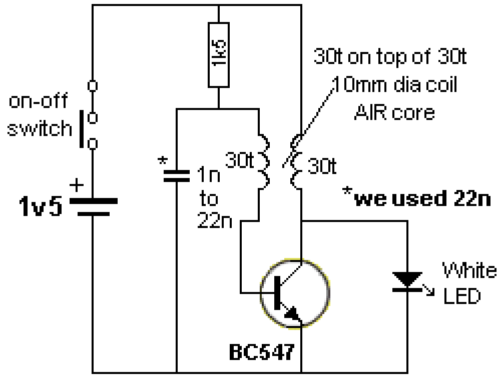
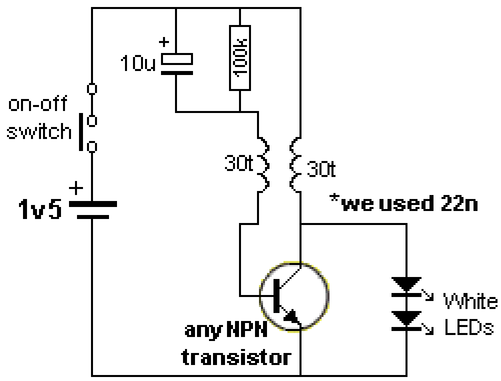
BIKE FLASHER - Amazing!

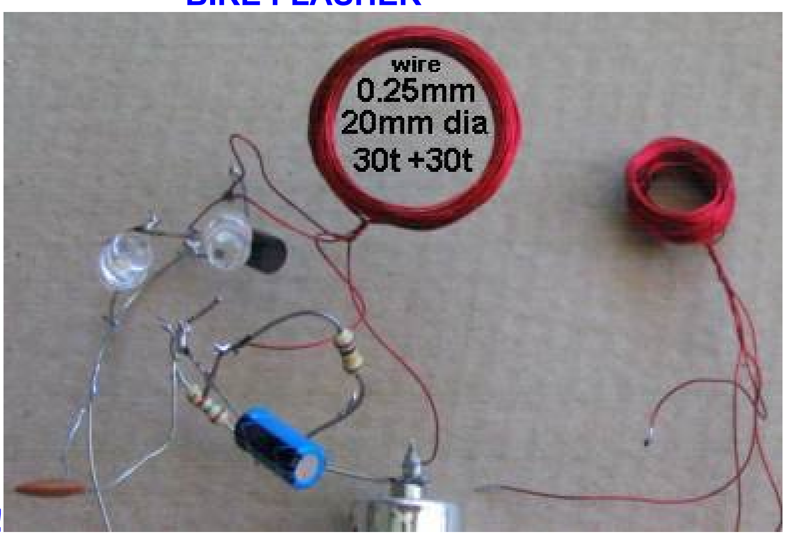
This bike flasher uses a single transistor to flash two white LEDs from a single cell. And it has **no core** for the transformer - just AIR!
All **Joule Thief** circuits you have seen, use a ferrite rod or toroid (doughnut) core and the turns are wound on the ferrite material. But this circuit proves the collapsing magnetic flux produces an increased voltage, even when the core is AIR. The fact is this: When a magnetic filed collapses quickly, it produces a higher voltage in the opposite direction and in this case the magnetic field surrounding the coil is sufficient to produce the energy we need.
Wind 30 turns on 10mm (1/2" dia) pen or screwdriver and then another 30 turns on top. Build the first circuit and connect the wires. You can use 1 or two LEDs. If the circuit does not work, swap the wires going to the base.

Now add the 10u electrolytic and 100k resistor (remove the 1k5). The circuit will now flash. You must use 2 LEDs for the flashing circuit.





BIKE FLASHER -



AMAZING!

THE IMPROVED BIKE FLASHER CIRCUIT

The original 30 turns + 30 turns coil is shown on the right. The circuit took 20mA to illuminate two LEDs.
The secret to getting the maximum energy from the coil (to flash the LEDs) is the maximum amount of air in the centre of the coil. Air cannot transfer a high magnetic flux so we provide a large area (volume) of low flux to provide the energy. The larger (20mm) coil reduced the current from 20mA to 11mA for the same brightness. This could be improved further but the coil gets too big. The two 30-turn windings must be kept together because the flux from the main winding must cut the feedback winding to turn ON the transistor **HARD**.
When the transistor starts to turn on via the 100k, it creates magnetic flux in the main winding that cuts the feedback winding and a positive voltage comes out the end connected to the base and a negative voltage comes out the end connected to the 100k and 10u. This turns the transistor ON more and it continues to turn ON until fully turned ON. At this point the magnetic flux is not expanding and the voltage does not appear in the feedback winding.
During this time the 10u has charged and the voltage on the negative lead has dropped to a lower voltage than before. This effectively turns off the transistor and the current in the main

winding ceases abruptly. The magnetic flux collapses and produces a voltage in the opposite direction that is higher than the supply and this is why the two LEDs illuminate. This also puts a voltage through the feedback winding that keeps the transistor OFF. When the magnetic flux has collapsed, the voltage on the negative lead of the 10u is so low that the transistor does not turn on. The 100k discharges the 10u and the voltage on the base rises to start the next cycle.
You can see the 100k and 1k5 resistors and all the other parts in a "birds nest" to allow easy experimenting.
Note: Changing the turns to 40t for the main winding and 20t for the feedback (keeping the turns tightly wound together by winding wire around them) reduced the current to 8-9mA.

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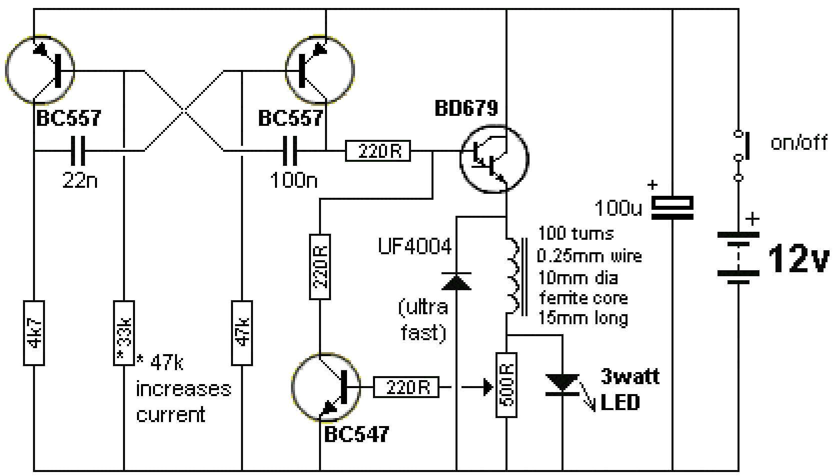
BUCK CONVERTER for 3watt LED



This circuit drives a 3watt LED. You have to be careful not to damage the LED when setting up the circuit. Add a 10R to the supply rail and hold it in your fingers. Make sure it does not get too hot and monitor the voltage across the resistor. Each 1v represents 100mA. The circuit will work and nothing will be damaged. If the resistor "burns your fingers" you have a short circuit.
The BC557 multivibrator has a "mark-to-space ratio" determined by the 22n and 33k, compared to the 100n and 47k, producing about 3:1   The BD679 is turned ON for about 30% of the time. This produces a very bright output, and takes about 170mA for 30% of the time. You cannot measure this current with a meter as it reads the peak value and the reading will be totally false. The only way to view the waveform is on a CRO, and calculate the current.
The 100-turn inductor allows the BD679 turn turn ON fully and "separates" the voltage on the emitter of the BC679 from the voltage on the top of the 3watt LED.
When the BD679 turns ON, the emitter rises to about 10v. But the top of the LED **NEVER** rises above 3.6v. The inductor "buffers" or "separates" these two voltages by producing a voltage across the winding equal to 6.4v and that's why the LED is not damaged.
When the transistor turns off (for 60% of the time), the magnetic flux produced by the current in the inductor collapses and produces a voltage in the opposite direction. This means the inductor now becomes a miniature battery and for a very short period of time it produces energy to illuminate the LED. The top of the inductor becomes negative and the bottom is positive. The current flows through the LED and through the Ultra High-Speed 1N4004 diode to complete the circuit. Thus the circuit takes advantage of the energy in the inductor.
A 500R pot is placed across the LED and a voltage is picked off the pot to turn on a BC547 transistor. This transistor "robs" some of the "turn-on" for the BD679 transistor to reduce the brightness of the LED.
Because the circuit is driving the LED with pulses, very high brightness is obtained with a low current.

Our eyes detect peak brightness and you can compare the performance of this circuit with a DC driven LED.

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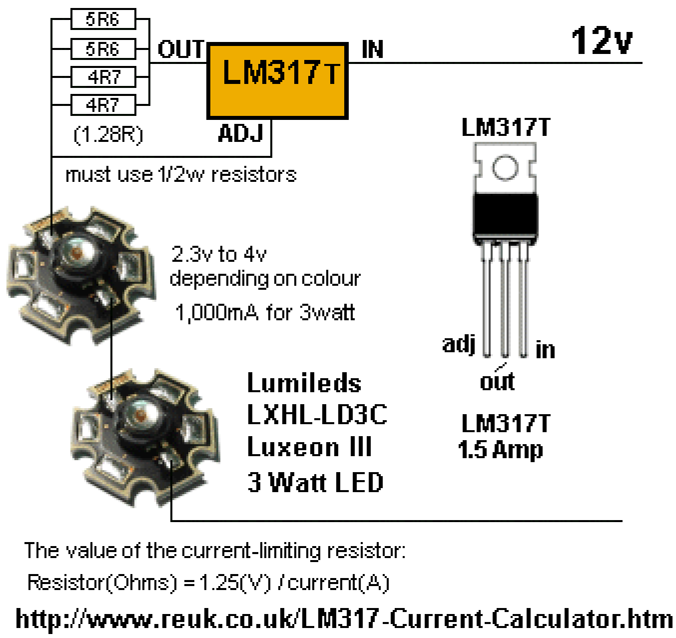
CONSTANT CURRENT DRIVES TWO 3WATT LEDs



This constant current circuit is designed to drive two 3-watt Luxeon LEDs. The LEDs require 1,000mA (1Amp) and have a characteristic voltage-drop across them of about 3.8v. Approximately 4v is dropped across the LM317T regulator and 1.25v across the current-limiting resistors, so the input voltage (supply) has to be 12.85v. A 12v battery generally delivers 12.6v. The LM 317T 3-terminal regulator will need to be heatsinked.
This circuit is designed for the LM series of regulator as they have a voltage differential of 1.25v between "adj" and "out" terminals.

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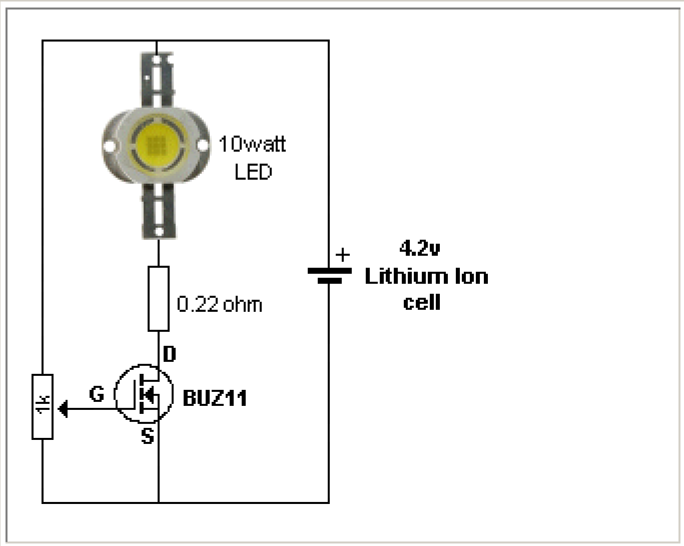
DIMMING A 10WATT LED

The following circuit is a request from a reader. He wanted to dim a 10 watt LED from a 4.2v Lithium Ion cell.
The current will be about 3 amps and a power MOSFET is needed to deliver this current.
The characteristic voltage across the LED is about 3.3v to 3.6v and this leaves very little voltage for the control circuit. The resistance of the MOSFET is about 0.05 ohms and very little voltage is lost here.
The 0.22 ohm (1 watt) resistor will drop about 650millivolts.
The LED will not be overloaded or damaged by this circuit. When the pot is adjusted from full brightness, the MOSFET will dissipate a lot of energy and will get very hot if not properly heatsinked.
You can buy two 3200mAhr Li-ion cells for $4.00 (posted) on eBay. Some suppliers want $15.00 per cell. You will need 4 cells in parallel to keep the current from each cell below 1 amp and this will allow the circuit to operate for about 2 hours.



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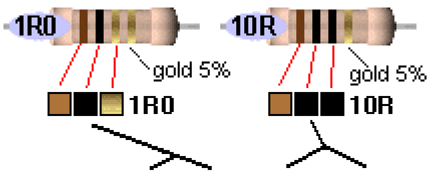


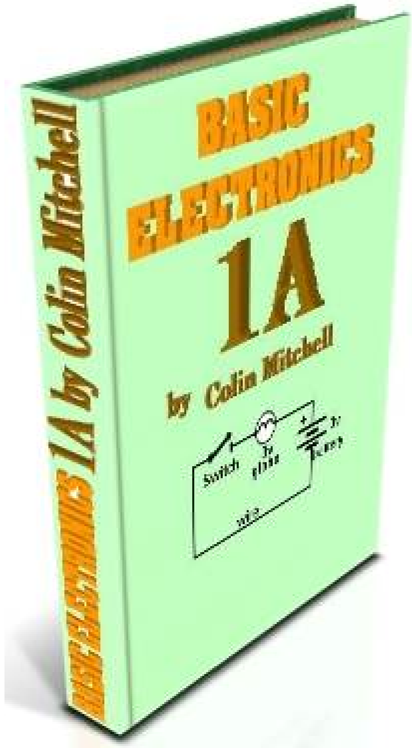
If 3rd band is gold, Divide by 10
If 3rd band is silver, Divide by 100
(to get 0.22ohms etc)

ROW	SILVER	GOLD	BLACK	BROWN	RED	ORANGE	YELLOW	GREEN
1-	R10	1R0	10R	100R	1K0	10K	100K	1M0
2-	R11	1R1	11R	110R	1K1	11K	110K	1M1
3-	R12	1R2	12R	120R	1K2	12K	120K	1M2
4-	R13	1R3	13R	130R	1K3	13K	130K	1M3
5-	R15	1R5	15R	150R	1K5	15K	150K	1M5
6-	R16	1R6	16R	160R	1K6	16K	160K	1M6
7-	R18	1R8	18R	180R	1K8	18K	180K	1M8
8-	R20	2R0	20R	200R	2K0	20K	200K	2M0
9-	R22	2R2	22R	220R	2K2	22K	220K	2M2
10-	R24	2R4	24R	240R	2K4	24K	240K	2M4
11-	R27	2R7	27R	270R	2K7	27K	270K	2M7
12-	R30	3R0	30R	300R	3K0	30K	300K	3M0
13-	R33	3R3	33R	330R	3K3	33K	330K	3M3
14-	R36	3R6	36R	360R	3K6	36K	360K	3M6
15-	R39	3R9	39R	390R	3K9	39K	390K	3M9
16-	R43	4R3	43R	430R	4K3	43K	430K	4M3
17-	R47	4R7	47R	470R	4K7	47K	470K	4M7
18-	R51	5R1	51R	510R	5K1	51K	510K	5M1
19-	R56	5R6	56R	560R	5K6	56K	560K	5M6
20-	R62	6R2	62R	620R	6K2	62K	620K	6M2
21-	R68	6R8	68R	680R	6K8	68K	680K	6M8
22-	R75	7R5	75R	750R	7K5	75K	750K	7M5
23-	R82	8R2	82R	820R	8K2	82K	820K	8M2
24-	R91	9R1	91R	910R	9K1	91K	910K	9M1
								10M (BLUE)

COLOR CODES FOR THE WHOLE E12/E24 RANGE OF RESISTORS

The twelve odd rows - 1, 3, 5... - represent values available in the E12 range only, plus 10M

go to: Talking Electronics Website



For any enquiries email Colin Mitchell

THE MULTIMETER

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TWO MULTIMETERS

There are basically two different types of MULTIMETER. ANALOGUE and DIGITAL
Analogue Multimeters have a NEEDLE or POINTER that moves across a scale.
Digital Multimeters have a numeric display of 3 or more digits. A Digital Multimeter with 3½ digits means the first digit shows only "1."

You really need both types to cover the number of tests needed for designing and repair-work. We will discuss how they work, how to use them and some of the differences between them.

The black (negative lead) ALWAYS stays in the

black hole and the red lead changes to the other red hole to measure 10 amps

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BUYING A MULTIMETER

There are many different types on the market.
The cost is determined by the number of ranges and also the extra features such as diode tester, buzzer (continuity), transistor tester, high DC current and others.
Since most multimeters are reliable and accurate, buy one with the greatest number of ranges at the lowest cost. The cheapest multimeters are on **eBay**.
This article explains the difference between an analogue meter and a digital meter.

Multimeters are sometimes called a "meter", a "VOM" (Volts-Ohms-Milliamps or Volt Ohm Meter) or "multi-tester" or even "a tester" - they are all the same.

One term used to describe a **DIGITAL MULTIMETER** is **3½ digits**.
This is the number of digits on the display. The first digit is usually made from two pixels and can only produce "1." This is called a half-digit. The other digits are full digits. The cheapest digital multimeters have 3½ digits. This will produce a reading of 1999 and the decimal point can produce values from 1.999 to 19.99 to 199.9 to 1999.
Another term is **DISPLAY COUNTS**. This is connected with the accuracy of the display, but since digital meters are accurate to 1% or less and we are using resistors with an accuracy of 5%, even a $10.00 digital meter will be perfect.

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USING A MULTIMETER

Analogue and **digital** multimeters have either a rotary selector switch or push buttons to select the appropriate function and range. Some Digital Multimeters (DMMs) are auto ranging; they automatically select the correct range of voltage, resistance, or current when doing a test. However you need to select the function.

Before making any measurement you need to know what you are checking. If you are measuring voltage, select the AC range (10v, 50v, 250v, or 1000v) or DC range (0.5v, 2.5v, 10v, 50v, 250v, or 1000v). If you are measuring resistance, select the Ohms range (x1, x10, x100, x1k, x10k). If you are measuring current, select the appropriate current range DCmA 0.5mA, 50mA, 500mA, 10A. Every multimeter is different however the photo below shows a low cost Analogue multimeter with the basic ranges.

An ANALOGUE MULTIMETER

The most important point to remember is this:
You must select a voltage or current range that is bigger or HIGHER than the maximum expected value, so the needle does not swing across the scale and hit the "end stop."
If you are using a DMM (Digital Multi Meter), the meter will indicate if the voltage or current is higher than the selected scale, by showing "OL" - this means "Overload." If you are measuring resistance such as 1M on the x10 range the "OL" means "Open Loop" and you will need to change the range. Some meters show "1' on the display when the measurement is higher than the display will indicate and some flash a set of digits to show over-voltage or over-current. A "-1" indicates the leads should be reversed for a "positive reading."
If it is an AUTO RANGING meter, it will automatically produce a reading, otherwise the selector switch must be changed to another range.

A typical DIGITAL Multimeter

The Common (negative) lead ALWAYS fits into the "COM" socket. The red lead fits into the red socket for Voltage and Resistance. Place the red lead (red banana plug) into "A" (for HIGH CURRENT "Amps") or mA,uA for LOW CURRENT.

The black "test lead" plugs into the socket marked "-" "Common", or "Com," and the red "test lead" plugs into the meter socket marked "+" or "V-W-mA."   The third banana socket measures HIGH CURRENT and the positive (red lead) plugs into this. You DO NOT move the negative "-" lead at any time.
The following two photos show the test leads fitted to a digital meter. The probes and plugs have "guards" surrounding the probe tips and also the plugs so you can measure high voltages without getting near the voltage-source.

Analogue meters have an "Ohms Adjustment" to allow for the change in voltage of the battery inside the meter (as it gets old).

"Ohms Adjust" is also called "ZERO SET"
The sensitivity of this meter is 20,000ohms/volt on the DC ranges and 5k/v on the AC ranges

Before taking a resistance reading (each time, for any of the Ohms scales) you need to "ZERO SET" the scale, by touching the two probes together and adjust the pot until the needle reads "0" (swings FULL SCALE). If the pointer does not reach full scale, the batteries need replacing. Digital multimeters do not need "zero adjustment."

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ANALOGUE Vs DIGITAL

You cannot say one meter is better than the other because BOTH have advantages and disadvantages.
An analogue multimeter is the "old style" and it puts a load on a circuit and this may change the reading to give an incorrect readout, but it has the advantage of the needle moving across the scale fairly quickly so you can sometimes see if the voltage is fluctuating.
It also gives a more-accurate result in some high frequency circuits as it does not pick up stray fields and produce a false reading.
Digital meters put almost no load on a circuit and produce accurate readings from both low-impedance and high-impedance circuits.
Digital meters can display very low resistances.
You must remember to turn a Digital meter OFF to prevent the battery going flat.

If you are testing a circuit containing a high-frequency oscillator, use BOTH an ANALOGUE and DIGITAL meter to check the reading. Sometimes the leads of a Digital multimeter will pick up signals and create a false reading.
Sometimes you will get a voltage reading with a Digital multimeter due to a high resistance leak and a zero reading with an Analogue meter. This is why you need **BOTH** meters.

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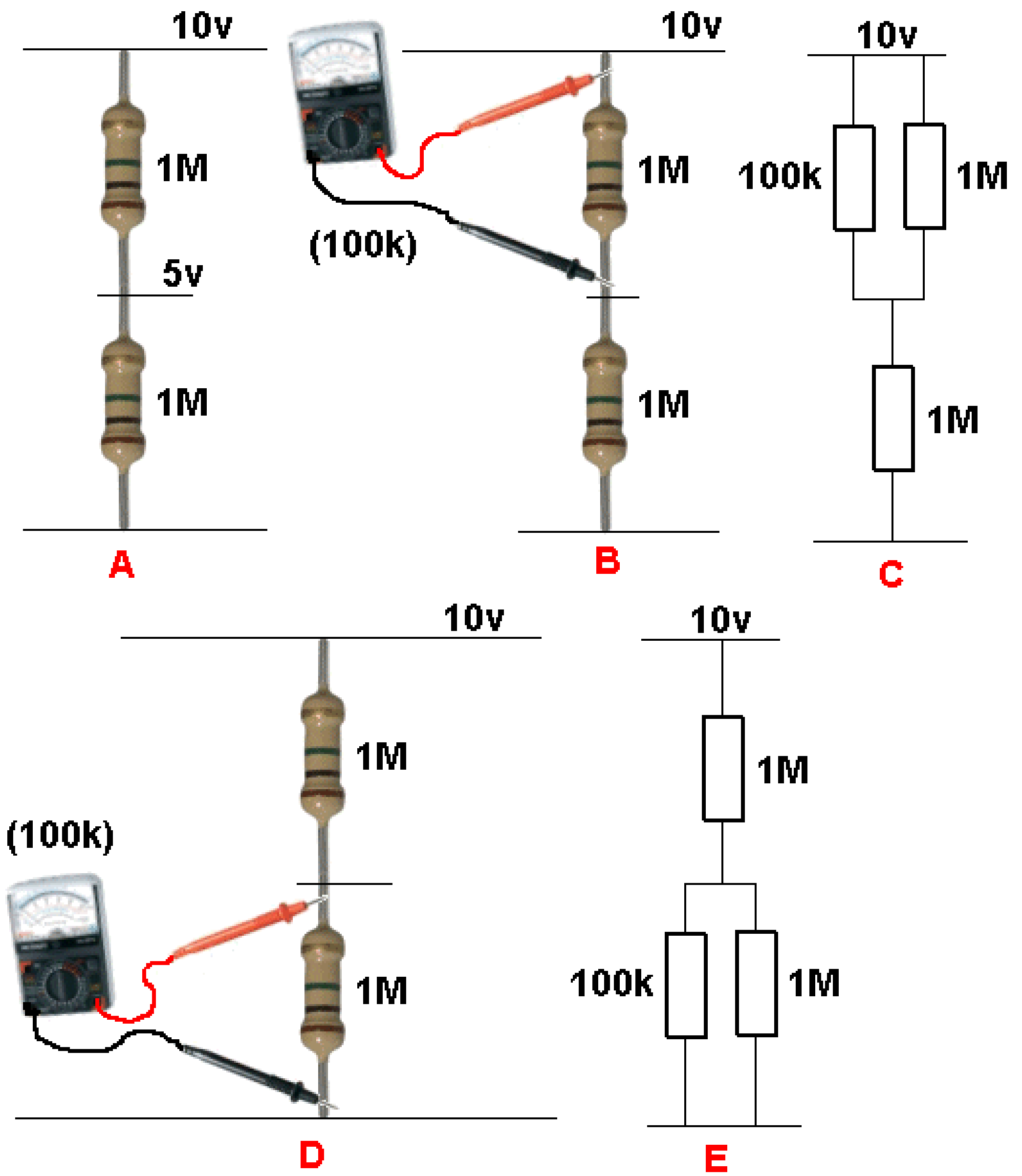
MEASURING VOLTAGE

Most of the readings taken with a multimeter will be VOLTAGE readings.
Before taking a reading, you should select the highest range and if the needle does not move up scale (to the right), you can select another range.
Always switch to the highest range before probing a circuit and keep your fingers away from the component being tested.
If the meter is Digital, select the highest range or use the auto-ranging feature, by selecting "V." The meter will automatically produce a result, even if the voltage is

AC or DC.
If the meter is not auto-ranging, you will have to select V= if the voltage is from a DC source or V~ if the voltage is from an AC source. DC means Direct Current (but this does not mean you select the CURRENT range - you are taking a voltage reading that is not rising and falling. That's why we say it is **DC** and do not say the words "direct current"). The voltage is coming from a battery or supply where it is steady and not "rising and falling."
You can measure the voltage at different points in a circuit by connecting the black probe to chassis. This is the 0v reference and is commonly called "Chassis" or "Earth" or "Ground" or "0v."
The red lead is called the "measuring lead" or "measuring probe" and it can measure voltages at any point in a circuit. Sometimes there are "test points" on a circuit and these are wires or loops designed to hold the tip of the red probe (or a red probe fitted with a mini clip).
You can also measure voltages ACROSS A COMPONENT. In other words, the reading is taken in PARALLEL with the component. It may be the voltage across a transistor, resistor, capacitor, diode or coil. In most cases this voltage will be less than the supply voltage.
If you are measuring the voltage in a circuit that has a HIGH IMPEDANCE, the reading will be inaccurate, up to 90% !!!, if you use a cheap analogue meter.

Here's a simple case.

The circuit below consists of two 1M resistors in series. The voltage at the mid point will be 5v when nothing is connected to the mid point. But if we use a cheap analogue multimeter set to 10v, the resistance of the meter will be about 100k, if the meter has a sensitivity of 10k/v and the reading will be incorrect.
Here how it works:
Every meter has a sensitivity. The sensitivity of the meter is the sensitivity of the movement and is the amount of current required to deflect the needle FULL SCALE. This current is very small, normally 1/10th of a milliamp and corresponds to a sensitivity of 10k/volt (or 1/30th mA, for a sensitivity of 30k/v).
If an analogue meter is set to 10v, the internal resistance of the meter will be 100k for a 10k/v movement.
If this multimeter is used to test the following circuit, the reading will be inaccurate.
The reading should be 5v as show in diagram **A**.
But the analogue multimeter has an internal resistance of 100k and it creates a circuit shown in **C**.
The top 1M and 100k from the meter create a combined PARALLEL resistance of 90k. This forms a series circuit with the lower 1M and the meter will read less than 1v
If we measure the voltage across the lower 1M, the 100k meter will form a value of resistance with the lower 1M and it will read less than 1v
If the multimeter is 30k/v, the readings will be 2v. See how easy it is to get a totally inaccurate reading.



If the reading is taken with a Digital Meter, it will be more accurate as a DMM does not take any current from the circuit (to activate the meter). In other words it has a very HIGH input impedance. Most Digital Multimeters have a fixed input resistance (impedance) of 10M - no matter what scale is selected. That's the reason for choosing a DMM for high impedance circuits. It also gives a reading that is accurate to about 1%.

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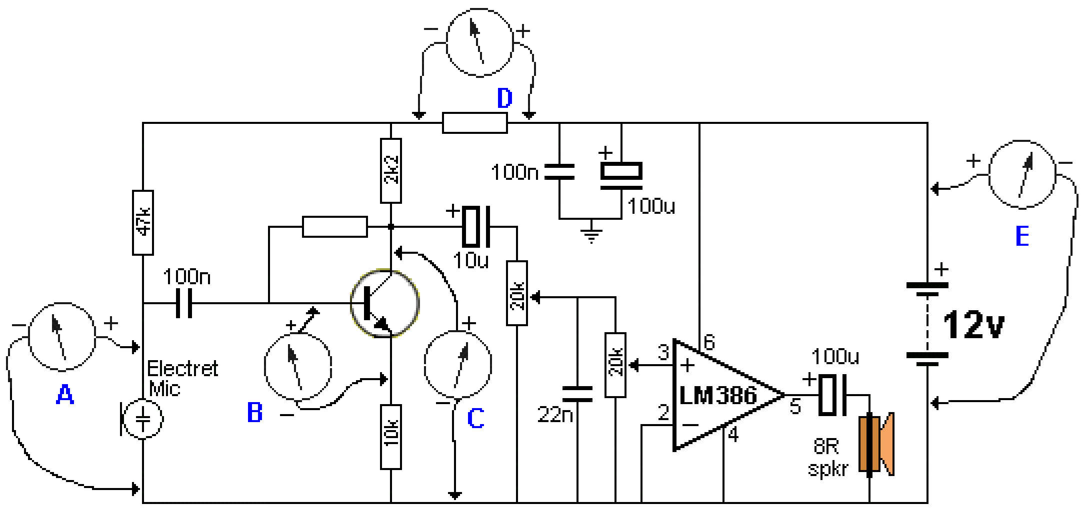
MEASURING VOLTAGES in a CIRCUIT

You can take many voltage-measurements in a circuit. You can measure "across" a component, or between any point in a circuit and either the positive rail or earth rail (0v rail). In the following circuit, the 5 most important voltage-measurements are shown. Voltage "A" is across the electret microphone. It should be between 20mV and 500mV. Voltage "B" should be about 0.6v. Voltage "C" should be about half-rail voltage. This allows the transistor to amplify both the positive and negative parts of the waveform. Voltage "D" should be about 1-3v. Voltage "E" should be the battery

voltage of 12v.



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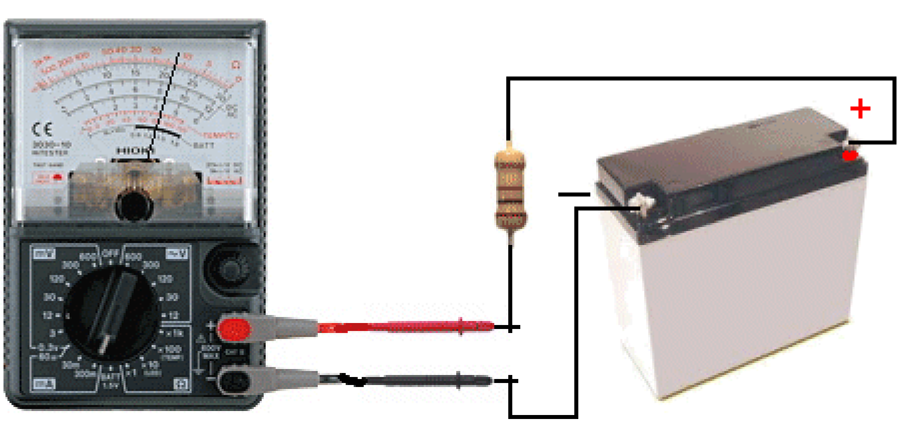
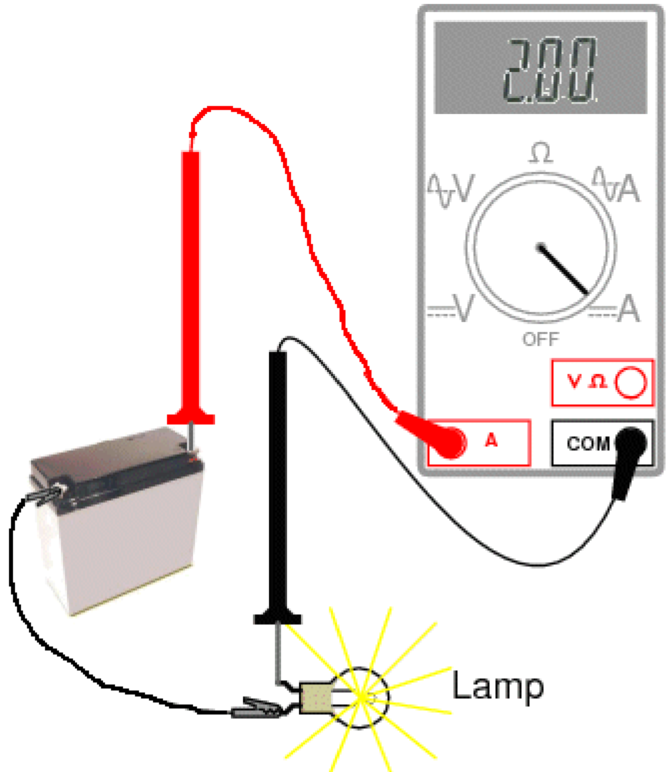
MEASURING CURRENT

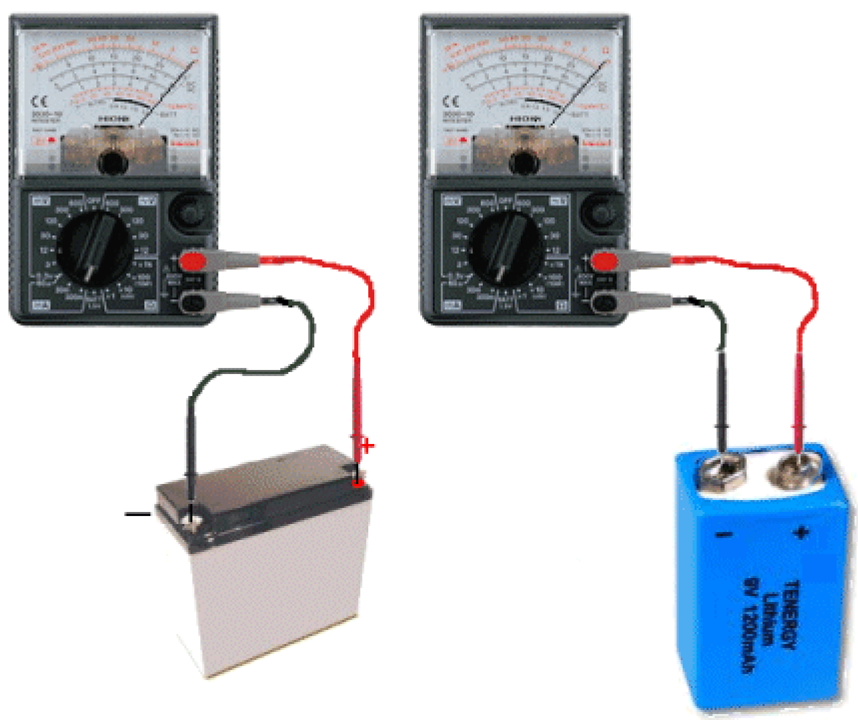
You will rarely need to take current measurements, however most multimeters have DC current ranges such as 0.5mA, 50mA, 500mA and 10Amp (via the extra banana socket) and some meters have AC current ranges. Measuring the current of a circuit will tell you a lot of things. If you know the normal current, a high or low current can let you know if the circuit is overloaded or not fully operational.

Current is always measured when the circuit is working (i.e: with power applied).
It is measured IN SERIES with the circuit or component under test.
The easiest way to measure current is to remove the fuse and take a reading across the fuse-holder. Or remove one lead of the battery or turn the project off, and measure across the switch.
If this is not possible, you will need to remove one end of a component and measure with the two probes in the "opening."
Resistors are the easiest things to desolder, but you may have to cut a track in some circuits. You have to get an "opening" so that a current reading can be taken.
The following diagrams show how to connect the probes to take a CURRENT reading.
Do not measure the current ACROSS a component as this will create a "short-circuit."
The component is designed to drop a certain voltage and when you place the probes across this component, you are effectively adding a "link" or "jumper" and the voltage at the left-side of the component will appear on the right-side. This voltage may be too high for the circuit being supplied and the result will be damage.





Measuring the current of a globe



Do NOT measure the CURRENT of a battery
(by placing the meter directly across the terminals)
A battery will deliver a very HIGH current
and damage the meter

Do not measure the "current a battery will deliver" by placing the probes across the terminals. It will deliver a very high current and damage the meter instantly. There are special battery testing instruments for this purpose.

When measuring across an "opening" or "cut," place the red probe on the wire that supplies the voltage (and current) and the black probe on the other wire. This will produce a "POSITIVE" reading.
A positive reading is an UPSCALE READING and the pointer will move across the scale - to the right. A "NEGATIVE READING" will make the pointer hit the "STOP" at the left of the scale and you will not get a reading. If you are using a Digital Meter, a negative sign "-" will appear on the screen to indicate the probes are around the wrong way. No damage will be caused. It just indicates the probes are connected incorrectly.
If you want an accurate CURRENT MEASUREMENT, use a digital meter.

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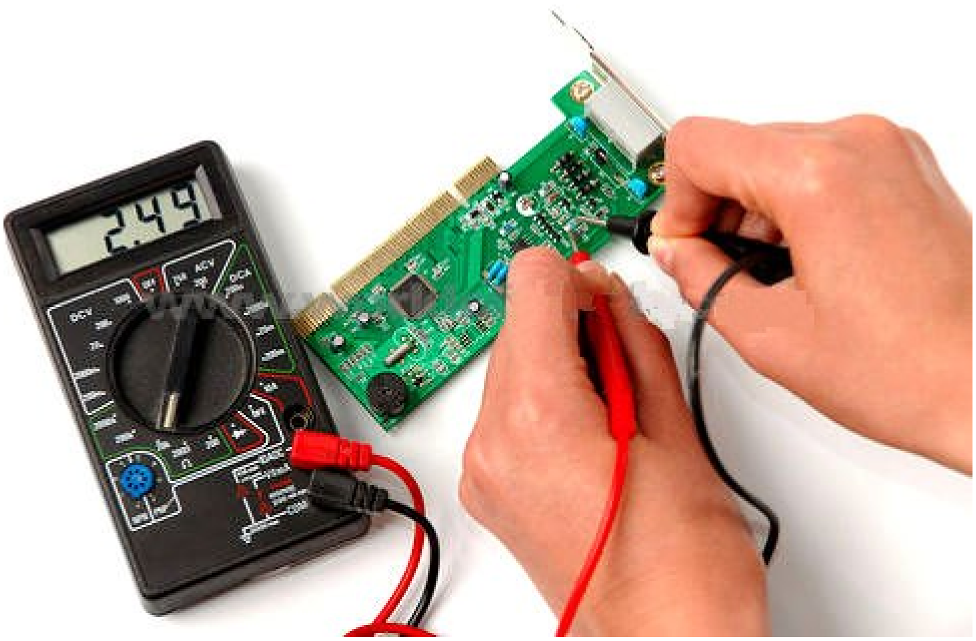
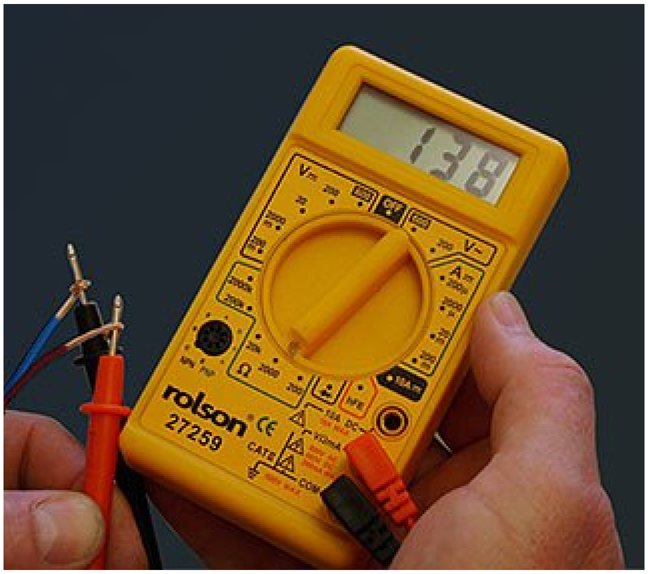
MEASURING RESISTANCE

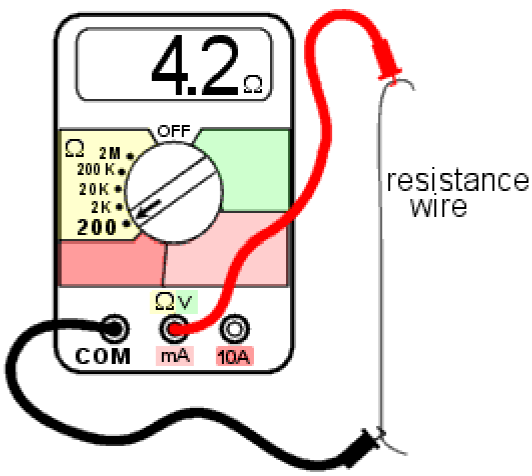
Turn a circuit off before measuring resistance.
If any voltage is present, the value of resistance will be incorrect.
In most cases you cannot measure a component while it is in-circuit. This is because the meter is actually measuring a voltage across a component and calling it a "resistance." The voltage comes from the battery inside the meter. If any other voltage is present, the meter will produce a false reading.
If you are measuring the resistance of a component while still "in circuit," (with the power off) the reading will be lower than the true reading.



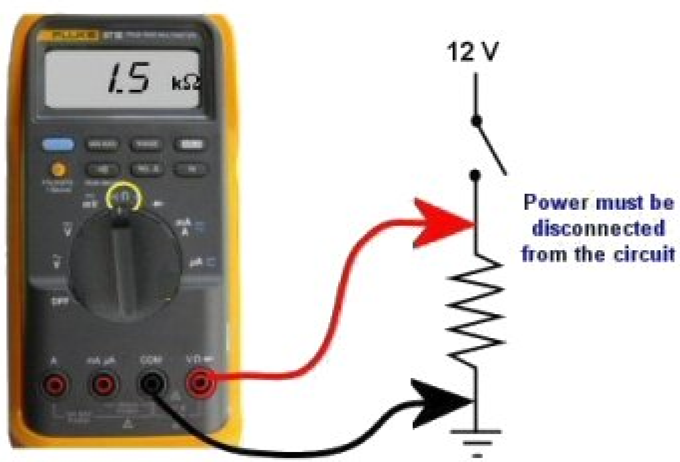
Measuring resistance



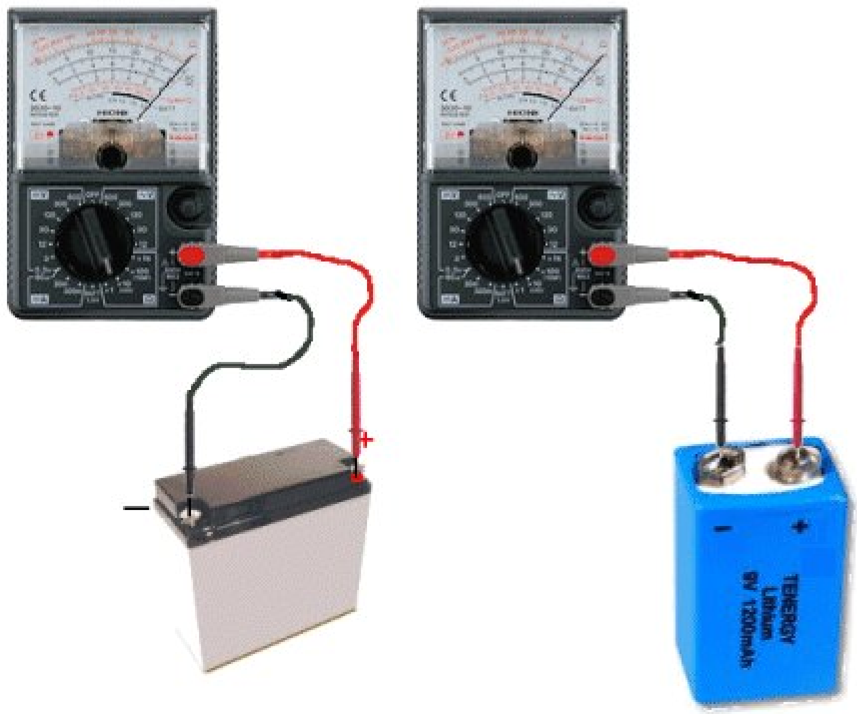
Measuring resistance of a heater (via the leads)



Measuring the resistance of a piece of resistance-wire



Measuring the resistance of a resistor



Do not measure the "Resistance of a Battery"

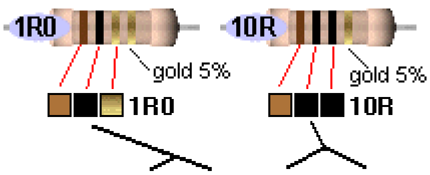
1. Do not measure the "resistance of a battery." The resistance of a battery (called the Internal impedance) is not measured as shown in the diagrams above. It is measured by creating a current-flow and measuring the voltage across the battery. Placing a multimeter set to **resistance** (across a battery) will destroy the meter.
2. Do not try to measure the resistance of any voltage or any "supply."

Resistance is measured in OHMs.
The resistance of a 1cm x 1cm bar, one metre long is 1 ohm.
If the bar is thinner, the resistance is higher. If the bar is longer, the resistance is higher.
If the material of the bar is changed, the resistance is higher.
When carbon is mixed with other elements, its resistance increases and this knowledge is used to make RESISTORS.
Resistors have RESISTANCE and the main purpose of a resistor is to reduce the CURRENT FLOW.
It's a bit like standing on a hose. The flow reduces.
When current flow is reduced, the output voltage is also reduced and that why the water does not spray up so high. Resistors are simple devices but they produce many different effects in a circuit.
A resistor of nearly pure carbon may be 1 ohm, but when non-conducting "impurities" are added, the same-size resistor may be 100 ohms, 1,000 ohms or 1 million ohms.
Circuits use values of less than 1 ohm to more than 22 million ohms.

Resistors are identified on a circuit with numbers and letters to show the exact value of resistance - such as 1k 2k2 4M7
The letter Ω (omega - a Greek symbol) is used to identify (or express) (or represent) the word "Ohm."
But this symbol is not available on some word-processors, so the letter "R" is used. The letter "E" is also sometimes used and both mean "Ohms."
A one-ohm resistor is written "1R" or "1E." It can also be written "1R0" or "1E0."
A resistor of one-tenth of an ohm is written "0R1" or "0E1." The letter takes the place of the decimal point.
10 ohms = 10R
100 ohms = 100R

1,000 ohms = 1k (k= kilo = one thousand)
10,000 ohms = 10k
100,000 ohms = 100k
1,000,000 ohms = 1M (M = MEG = one million)

The size of a resistor has nothing to do with its resistance. The size determines the wattage of the resistor - how much heat it can dissipate without getting too hot.
Every resistor is identified by colour bands on the body, but when the resistor is a surface-mount device, numbers are used and sometimes letters.
You MUST learn the colour code for resistors and the following table shows all the colours for the most common resistors from 1/10th of an ohm to 22 Meg ohms for resistors with 5% and 10% tolerance.



If 3rd band is gold, Divide by 10
If 3rd band is silver, Divide by 100
(to get 0.22ohms etc)

ROW	SILVER	GOLD	BLACK	BROWN	RED	ORANGE	YELLOW	GREEN
1-	R10	1R0	10R	100R	1K0	10K	100K	1M0
2-	R11	1R1	11R	110R	1K1	11K	110K	1M1
3-	R12	1R2	12R	120R	1K2	12K	120K	1M2
4-	R13	1R3	13R	130R	1K3	13K	130K	1M3
5-	R15	1R5	15R	150R	1K5	15K	150K	1M5
6-	R16	1R6	16R	160R	1K6	16K	160K	1M6
7-	R18	1R8	18R	180R	1K8	18K	180K	1M8
8-	R20	2R0	20R	200R	2K0	20K	200K	2M0
9-	R22	2R2	22R	220R	2K2	22K	220K	2M2
10-	R24	2R4	24R	240R	2K4	24K	240K	2M4
11-	R27	2R7	27R	270R	2K7	27K	270K	2M7
12-	R30	3R0	30R	300R	3K0	30K	300K	3M0
13-	R33	3R3	33R	330R	3K3	33K	330K	3M3
14-	R36	3R6	36R	360R	3K6	36K	360K	3M6
15-	R39	3R9	39R	390R	3K9	39K	390K	3M9
16-	R43	4R3	43R	430R	4K3	43K	430K	4M3
17-	R47	4R7	47R	470R	4K7	47K	470K	4M7
18-	R51	5R1	51R	510R	5K1	51K	510K	5M1
19-	R56	5R6	56R	560R	5K6	56K	560K	5M6
20-	R62	6R2	62R	620R	6K2	62K	620K	6M2
21-	R68	6R8	68R	680R	6K8	68K	680K	6M8
22-	R75	7R5	75R	750R	7K5	75K	750K	7M5
23-	R82	8R2	82R	820R	8K2	82K	820K	8M2
24-	R91	9R1	91R	910R	9K1	91K	910K	9M1
								10M (BLUE)

COLOR CODES FOR THE WHOLE E12/E24 RANGE OF RESISTORS
The twelve odd rows - 1, 3, 5... - represent values available in the E12 range only, plus 10M

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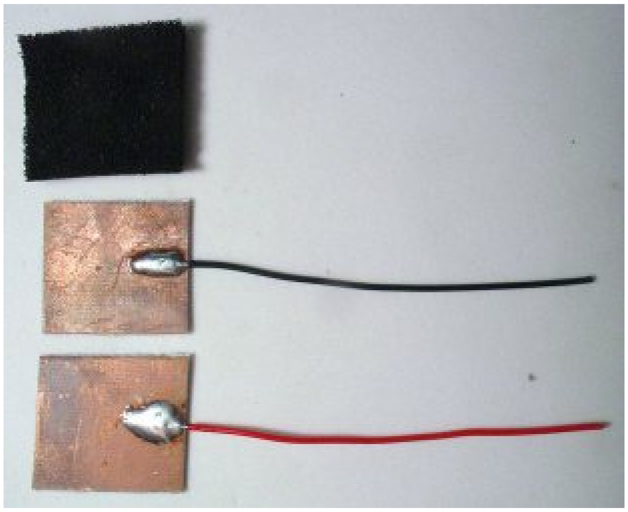
MAKE YOUR OWN RESISTOR

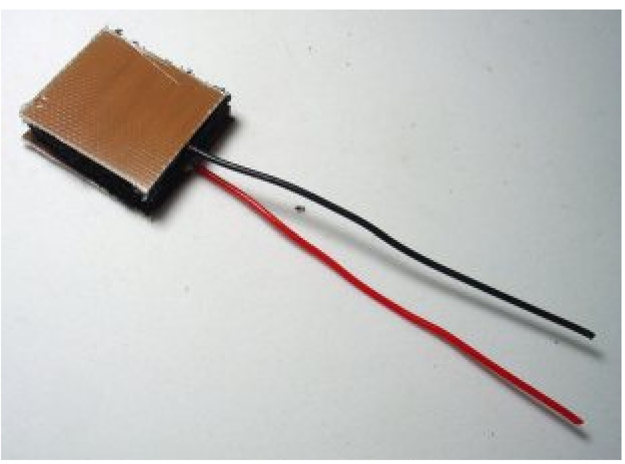
Make your own variable resistor that changes resistance according to the pressure.
Use a piece of conductive foam used to package Integrated Circuits. You can ask at an electronics shop.
Use two coins or pieces of printed circuit board or aluminium foil for the top and bottom conductors.
You can solder wires to the PC board or fold the aluminium foil over a few times to hold the wires.
The resistance of the foam will reduce as you press on the "cell."
The actual resistance-values will depend on the size of the foam, the thickness and

pressure.
This cell is a very simple cell called a **LOAD CELL**.

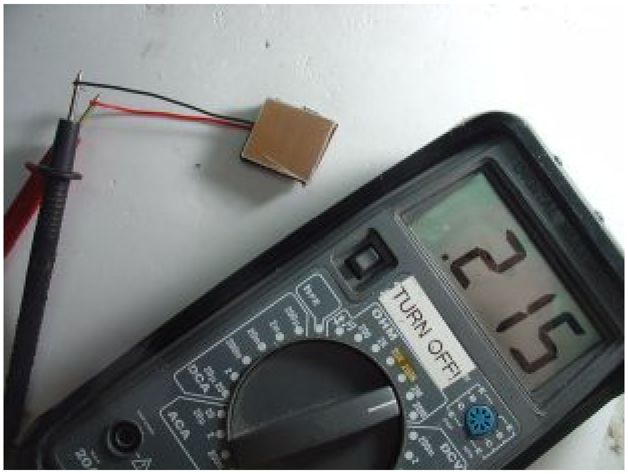


The top and bottom "plates"

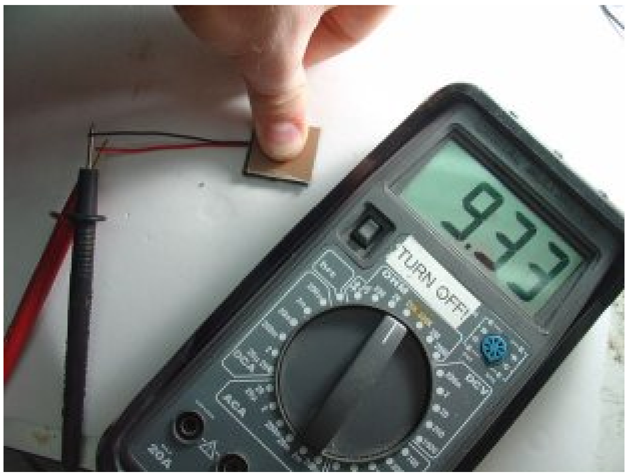
The foam is placed between the plates.



The complete LOAD CELL



The resistance of the unloaded LOAD CELL



The fully loaded resistance can be as low as 9,330 ohms

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MEASURING CONTINUITY

CONTINUITY is the same as **ZERO OHMS** or the resistance of a short length of wire. It can also mean the resistance through a switch or globe or a low-value resistor.
It basically means a "PATH" and sometimes refers to a whole circuit when the switch is closed. In other words CONTINUITY means we have a "circuit." We have "current flowing" and generally refers to a low-resistance circuit.
Both ANALOGUE and DIGITAL multimeters can measure CONTINUITY and you have to work out the approximate value of resistance for the circuit you are testing, - BEFORE TAKING A READING.
If the reading is above 300 ohms or contains a diode, you cannot use a DIGITAL MULTIMETER as the buzzer on the continuity setting will not respond.

The project being tested must not have the power applied as the resistance ranges on a multimeter are actually measuring a voltage across the leads and any voltage on the circuit or contained in any electrolytics, will upset the reading.

To take a reading with an **ANALOGUE** multimeter, select the x1 setting and the pointer will move across the scale to the actual value of resistance.
It it move full scale, you have ZERO OHMS resistance and this can mean a short-circuit or continuity via a wire.
If a diode is in the circuit you must also reverse the leads to get a reading.
The resistance of a globe will be very low when it is not illuminated, so don't think a fault is present.
Measuring CONTINUITY is the same as measuring LOW RESISTANCE.

To take a reading with a **DIGITAL** multimeter, select the buzzer setting. It will respond if the resistance is less than 300 ohms.   It will not respond if a diode is in the circuit.

Meter set to BUZZER - CONTINUITY

You can also use the x1 resistance setting to get an accurate value of resistance. Touch the probes together to get the initial reading and subtract this value from the final reading.
When probing a circuit containing electrolytics, you may get a beep from the buzzer. This indicates the resistance is low because the multimeter is charging the electrolytic and it will beep until the electrolytic is charged to about 0.7v.
The same applies when probing across the power rails of a circuit. The circuit may contain electrolytics that will charge when probing and the buzzer will beep.
The Digital multimeter is actually detecting a voltage less than 0.7v across the probes and is created by a voltage-divider network inside the meter.
The voltage divider put 2v across the probes and when this drops to less than 0.5v, the buzzer is activated. That why it odes not buzz when testing a diode as the diode drops the voltage to 0.6v.

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MEASURING A DIODE

A diode can be measured to see if it is "open" or "damaged" or "working" by placing the probes across the component.
If the diode is "open" (it will not work), the needle will NOT swing across the scale when touching the component with the probes in one direction or when the probes are reversed.
If the diode is "damaged" (does not work), the needle will swing fully across the scale when touching the component with the probes in one direction or when the probes are reversed.
If the diode is FUNCTIONAL, (works) the needle will swing about mid-way when touching the leads of the diode in one direction and it will not move when the probes are reversed.

WHY?

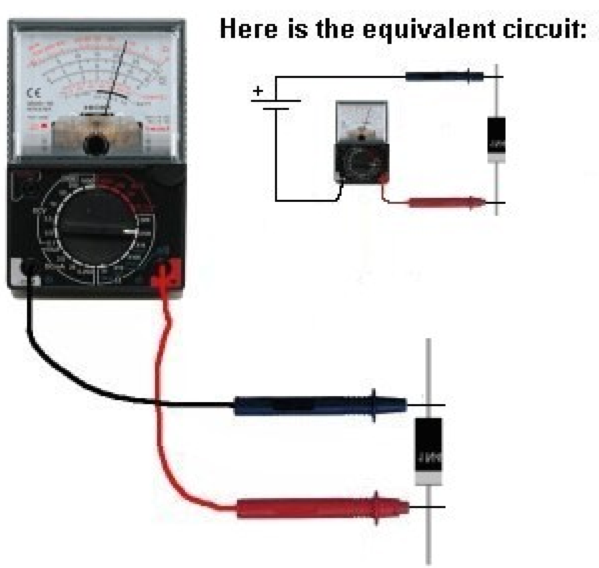
The positive of the battery inside an analogue multimeter comes out the black probe and that is why you will get a reading when the probers are "around the wrong way." The needle will swing a different amount for each resistance setting on the dial as the needle represents 0.6v drop and NOT an actual resistance.

There are two things you must remember.
1. When the diode is measured in one direction, the needle will will **not move at**

all. The technical term for this is the diode is **reverse biased**. It will not allow any current to flow. Thus the needle will not move.
When the diode is connected around the other way, the needle will swing to the right (move up scale) to about 80% of the scale. This position represents the voltage drop across the junction of the diode and is NOT a resistance value. If you change the resistance range, the needle will move to a slightly different position due to the resistances inside the meter. The technical term for this is the diode is **forward biased**. This indicates the diode is not faulty.
The needle will swing to a slightly different position for a "normal diode" compared to a Schottky diode. This is due to the different junction voltage drops.
However we are only testing the diode at very low voltage and it may break-down when fitted to a circuit due to a higher voltage being present or due to a high current flowing.

2. The leads of an **Analogue Multimeter** have the positive of the battery connected to the black probe and the readings of a "good diode" are shown in the following two diagrams:

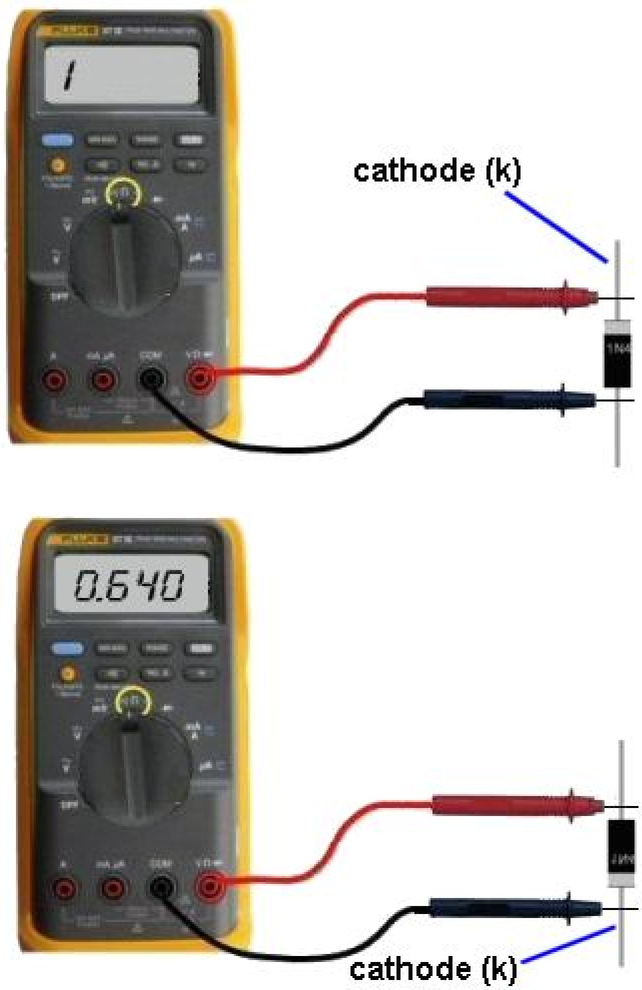
The diode is REVERSE BIASED in the diagram above and diodes not conduct.



The diode is FORWARD BIASED in the diagram above and it conducts

TESTING A DIODE ON A DIGITAL METER

A Digital multimeter will measure the voltage-drop across the diode when the probes are connected in one direction (approx 0.640 on the scale) and a high reading (1) in the other direction. You need to select the "DIODE" setting on the dial as the other settings will produce a meaningless reading.



Some DIGITAL MULTIMETERS will show mV drop across the diode when the setting on the meter is "diode" or the "x1" or "x10" resistance range.

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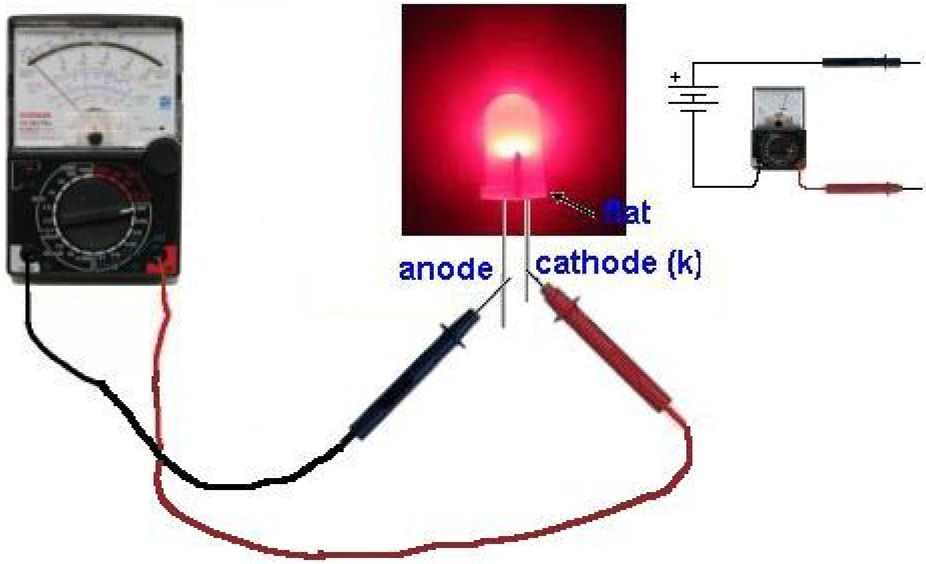
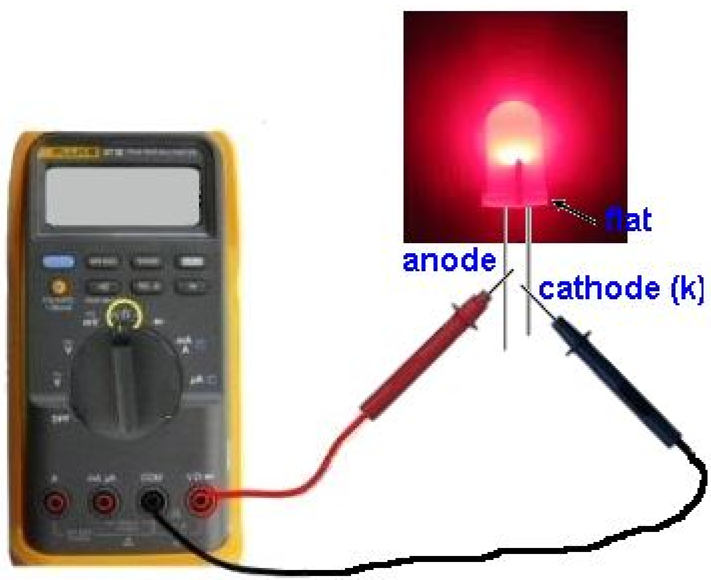
TESTING A LED

Some multimeters will test LEDs.
It depends on the voltage of the battery inside the case of the multimeter.
Many analogue multimeters have a single 1.5v cell and these cannot test LEDs.
Analogue Multimeters with 3v (for the resistance ranges) can test some LEDs.
White LEDs need about 3.6v and they may not illuminate on 3v.



The negative lead of an ANALOGUE meter is POSITIVE!
The multimeter must have 3v (2 cells)

Digital multimeters have a 9v battery and they will illuminate all colour LEDs when the leads are placed as shown in the diagram:



A Digital meter will illuminate all LEDs and the black probe touches the cathode.

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TESTING A TRANSISTOR WITH A DIGITAL METER

Testing a transistor with a **Digital Meter** must be done on the "DIODE" setting as a digital meter does not deliver a current through the probes on some of the resistance settings and will not produce an accurate reading.
The "DIODE" setting must be used for diodes and transistors. It should also be called a "TRANSISTOR" setting.

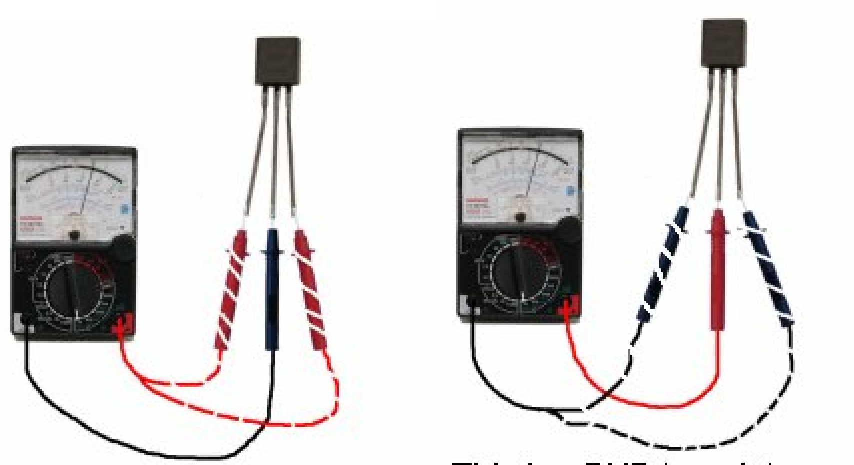
TESTING A TRANSISTOR WITH AN ANALOGUE METER

The first thing you may want to do is test an unknown transistor for COLLECTOR, BASE AND EMITTER. You also want to perform a test to find out if it is NPN or PNP. That's what this test will provide.
You need a cheap multimeter called an ANALOGUE METER - a multimeter with a

scale and pointer (needle).
It will measure resistance values (normally used to test resistors) - (you can also test other components) and Voltage and Current. We use the resistance settings. It may have ranges such as "x10" "x100" "x1k" "x10"
Look at the resistance scale on the meter. It will be the top scale.
The scale starts at zero on the right and the high values are on the left. This is opposite to all the other scales.
When the two probes are touched together, the needle swings FULL SCALE and reads "ZERO." Adjust the pot on the side of the meter to make the pointer read exactly zero.

How to read: "x10" "x100" "x1k" "x10"
Up-scale from the zero mark is "1"
When the needle swings to this position on the "x10" setting, the value is 10 ohms.
When the needle swings to "1" on the "x100" setting, the value is 100 ohms.
When the needle swings to "1" on the "x1k" setting, the value is 1,000 ohms = 1k.
When the needle swings to "1" on the "x10k" setting, the value is 10,000 ohms = 10k.
Use this to work out all the other values on the scale.
Resistance values get very close-together (and very inaccurate) at the high end of the scale. [This is just a point to note and does not affect testing a transistor.]

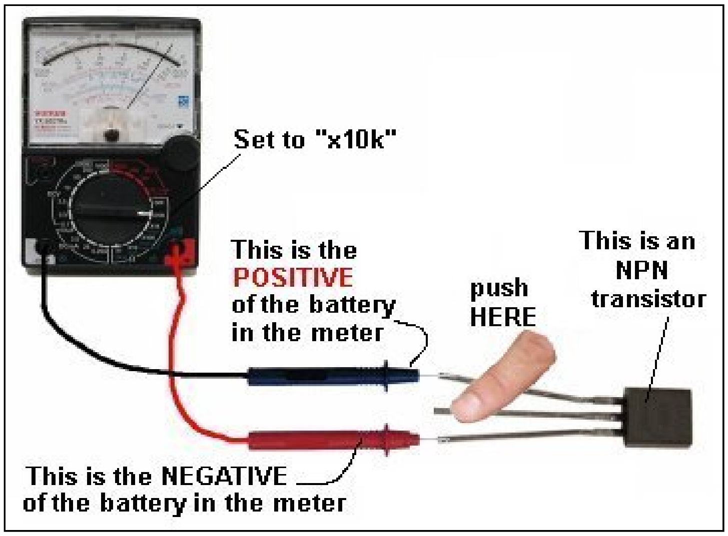
Step 1 - FINDING THE BASE and determining NPN or PNP
Get an unknown transistor and test it with a multimeter set to "x10"
Try the 6 combinations and when you have the black probe on a pin and the red probe touches the other pins and the meter swings nearly full scale, you have an NPN transistor. The black probe is BASE
If the red probe touches a pin and the black probe produces a swing on the other two pins, you have a PNP transistor. The red probe is BASE
If the needle swings FULL SCALE or if it swings for more than 2 readings, the transistor is **FAULTY**.

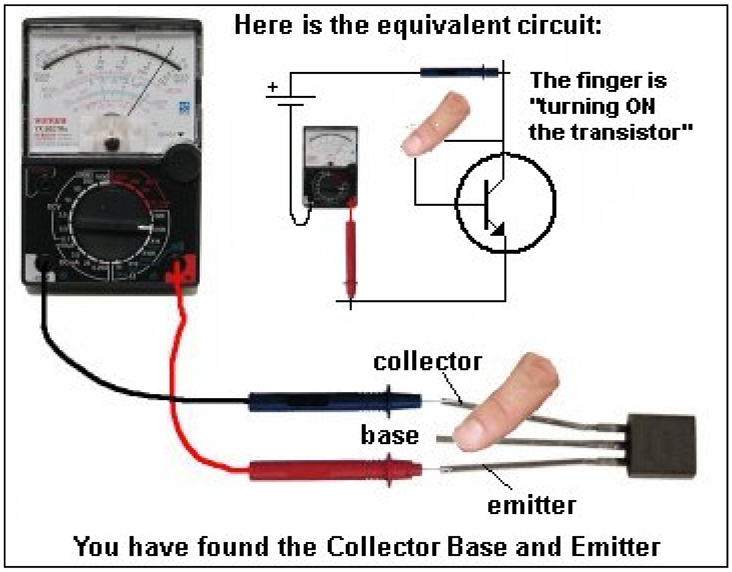


This is an NPN transistor
The black probe is the BASE

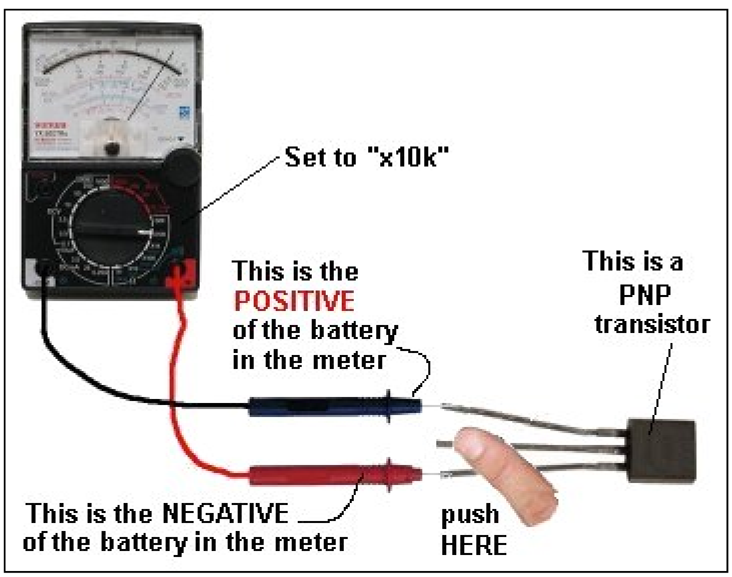
This is a PNP transistor
The red probe is the BASE

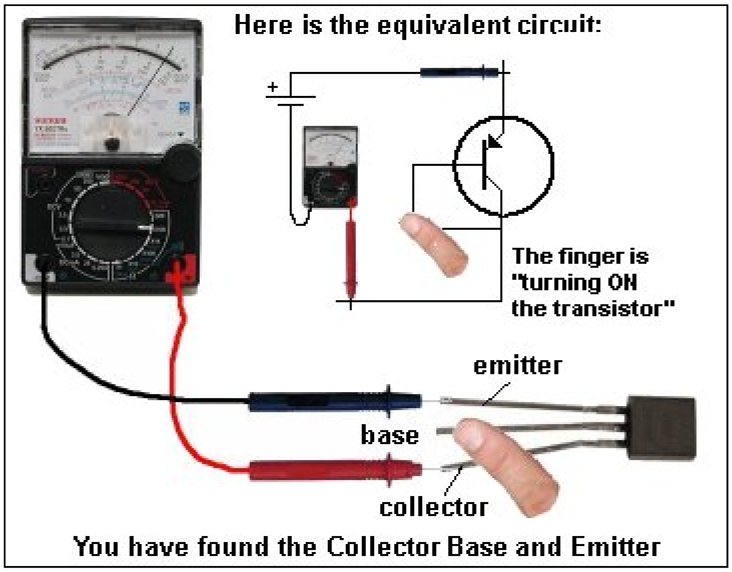
Step 2 - FINDING THE COLLECTOR and EMITTER
Set the meter to "x10k."
For an NPN transistor, place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.





For a PNP transistor, set the meter to "x10k" place the leads on the transistor and when you press hard on the two leads shown in the diagram below, the needle will swing almost full scale.





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For more details on testing components with a multimeter, see:
Testing Electronic Components.

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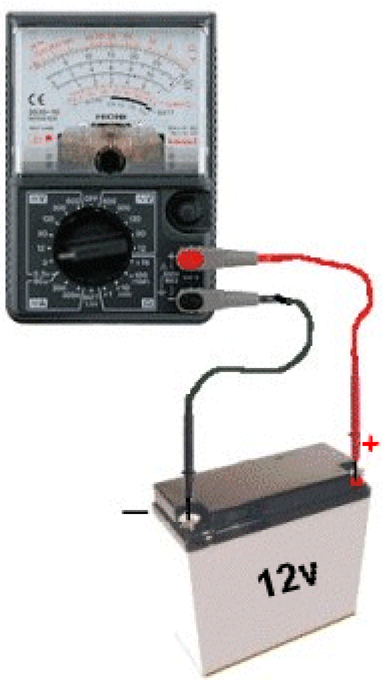
MULTIMETER TEST

1. What is the reading on the multimeter:



Answer

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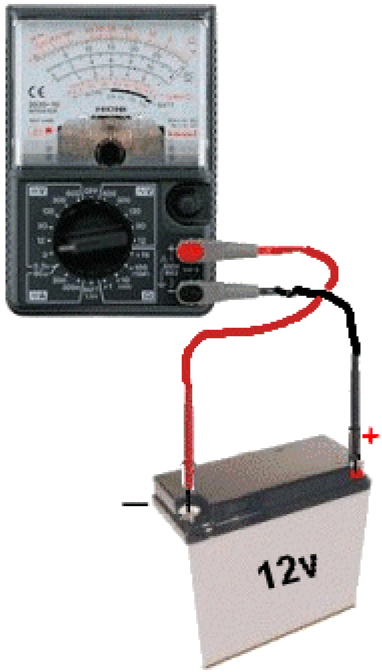
2. What is the reading on the multimeter:



Answer

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3. What is the reading on the multimeter:

Answer

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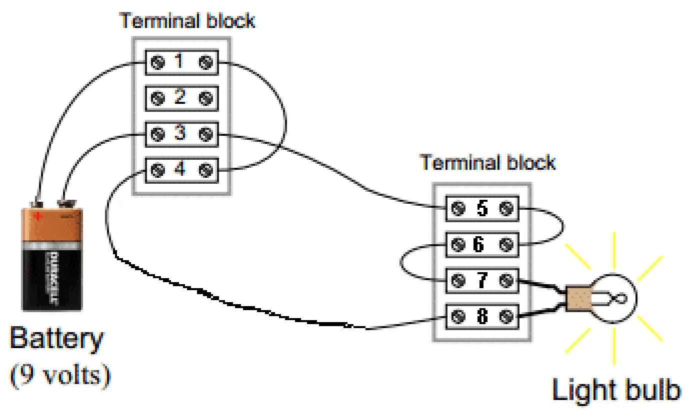
4. What is the voltage between the following points:



Between 1 & 3	Between 5 & 7	Between 3 & 8	Between 1 & 7
Answer	**Answer**	**Answer**	**Answer**

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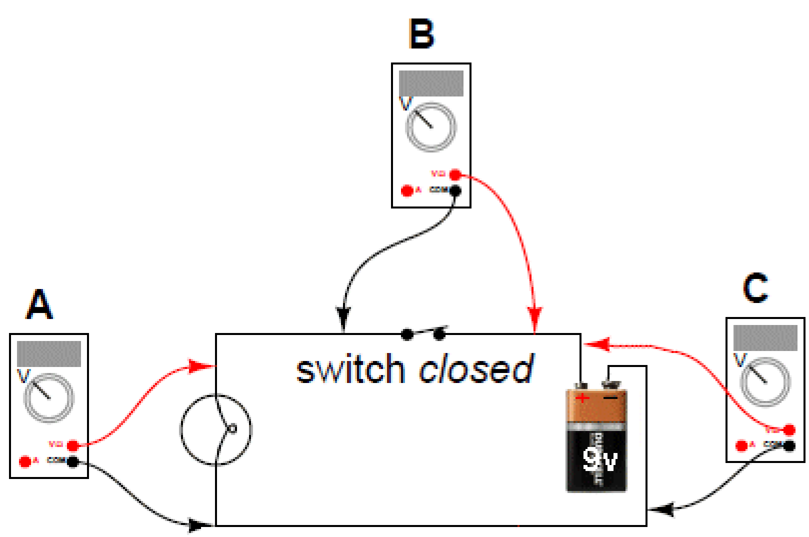
5. What is the voltage on each multimeter:



Meter A	Meter B	Meter C
Answer	**Answer**	**Answer**

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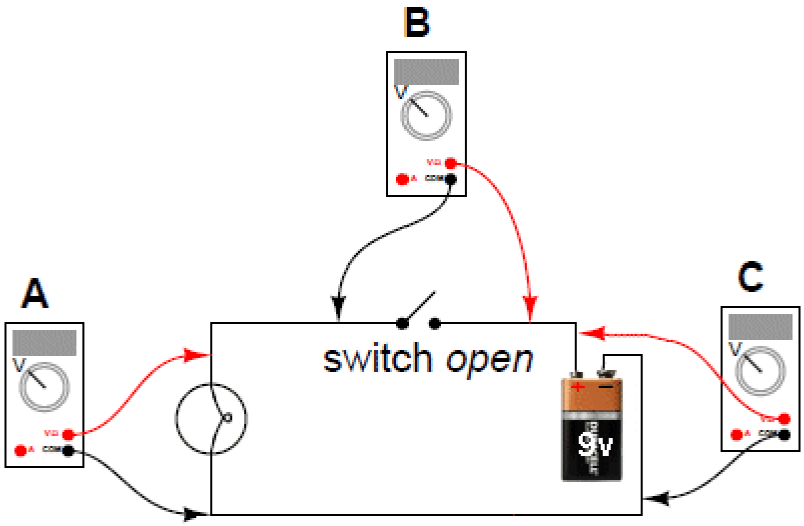
6. What is the voltage on each multimeter:



Meter A

Answer

Meter B

Answer

Meter C

Answer

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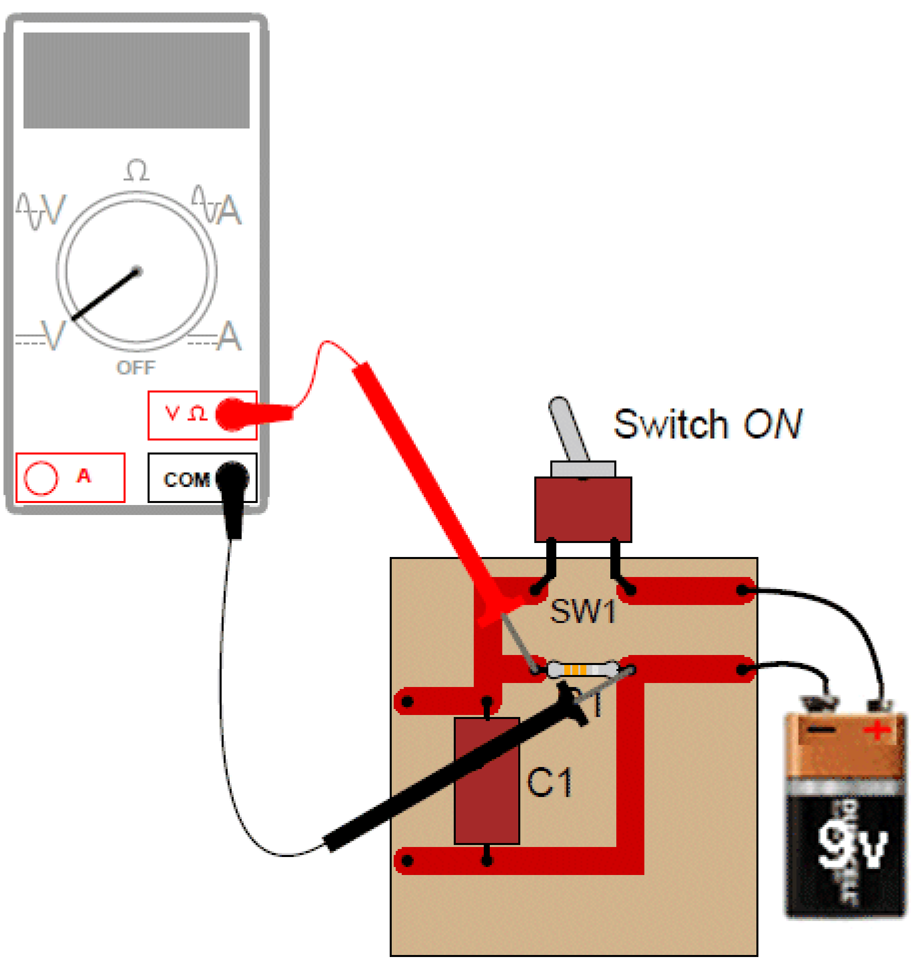
7. What is the reading on the multimeter:



Answer

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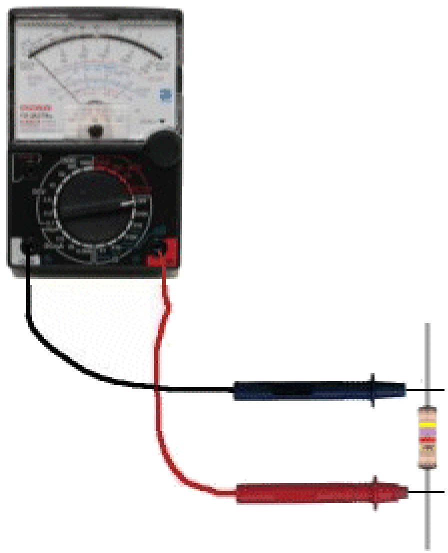
8. The multimeter has three resistance ranges: **x1 ohms** **x100 ohms** **x10k ohms**.
How far across the scale will the needle move on each range for a 4k7 resistor:



x1	**x100**	**x10k**
Answer	**Answer**	**Answer**

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9. The resistance ranges on an ANALOGUE multimeter use the battery inside the case to move the pointer. If the multimeter is left on "**ohms range**" with the probes apart, will the battery go flat?

Answer

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